DEFINITE PROJECT REPORT

BURFELL PROJECT

BY THE

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED FOR

THE STATE ELECTRICITY AUTHORITY

GOVERNMENT OF ICELAND

APRIL 1965

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HARZA ENGINEERING COMPANY INTERNATIONAL
CONSULTING ENGINEERS
RIVER PROJECTS

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CHICAGO, ILLINOIS

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TELEX NUMBER 312-222-9334

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BURFELL HYDROELECTRIC PROJECT
DEFINITE PROJECT REPORT

The State Electricity Authority
P.O. Box 40
Reykjavík, Iceland

Gentlemen:

Introduction

This Definite Project Report is the result of studies which have continued since 1959. These studies have been unusually complete with respect to field investigations and engineering analyses. Our company has made important contributions to the engineering of the Burfell Project since its inception by the Government of Iceland. We have prepared fourteen reports either on the Burfell Project or bearing some direct relation thereto. Each is summarized in Appendix A hereto. We have been engaged on engineering of Iceland's hydroelectric resources since 1957 and, in addition to the above reports, have made studies and reports on several other potential hydroelectric projects in Iceland.

The Burfell Project has now advanced to a definite project status. Construction of the primary access road was begun in the late summer of 1964. Arrangements for financing have been initiated and are in progress. Negotiations are proceeding aimed towards serving the loads of an aluminium smelter. Enabling legislation is under active consideration by the Government of Iceland. Engineering designs, begun in early 1964 by our company, are continuing on the basis of awarding the general construction contract and purchase contracts for turbines, governors, and generators by early 1966. Hydraulic model studies aimed to finalize the designs of the Thjorsa diversion features are in progress in Norway. The results thereof, expected in a few months, will permit proceeding further with the engineering designs of the river diversion features.

The main body of this Report summarizes the engineering for a Definite Project at Burfell to enlarge the existing regional system to supply the normal power and energy loads of Southwest Iceland plus that of three increments of an aluminium smelter. We understand that the first potline of the smelter would be fully operational by mid-1969. Two one-half potline increments would be added later, each at three-year intervals. Burfell will be scheduled to assist in meeting these overall loads.

Appendix B of this Report presents two other schedulings for the construction of the Burfell Project. The first involves the addition of the Project to the Southwest Iceland Power Supply System with the first potline added in mid-1969 and the second in mid-1972. The second scheduling presents the Burfell Project constructed in five Stages to meet the normal load growth of Southwest Iceland without any smelter loads.

Assuming the addition of two potlines of smelter loads, additional major industrial loads which may need power supplies prior to about 1974 would require the construction of other new generating plants which are not discussed in this Report. Additional new capacity would be required by about the end of 1975, with the smelter and fertilizer plant additions representing the only new major interim industrial loads. Engineering detail is presented in the several chapters and appendices of this Report. A brief summary follows.

Project Description

The Burfell Project power generating facilities will be located on the Thjorsa about 100 kilometers east of Reykjavik. Water will be diverted by a low dam on the river north of the mountain, Burfell, via a canal into a regulating pond situated behind a low dike. Other dikes in the vicinity will serve to retain the Thjorsa within its present channel. Water will be conducted from the regulating pond by a short canal, then through a tunnel and subsurface penstocks to a surface indoor-type powerhouse located at the west base of the small mountain, Samsstadamúli. The powerhouse will contain ultimately six generating units of 35 megawatts (MW) each. From the powerhouse, the water will be conducted through a short tailrace canal to the Fossá, thence via that tributary for two kilometers and returned to the Thjorsa. A gross head of about 118.5 meters will be developed.

Transmission facilities of the Burfell Project will convey the power and energy generated at the powerhouse to load centers in the Reykjavík area and at Straumsvík, the selected site for the aluminium smelter. A single circuit 230 kilovolt (KV) transmission line will extend from the sending substation near the powerhouse to Irafoss, where an emergency intertie will be made to the existing Sog generating plants, then on to the Geitháls receiving substation located about seven kilometers east of Reykjavík. From Geitháls a double circuit 230 KV transmission line will extend to the receiving substation at the smelter. The Geitháls receiving substation will include a 138 KV portion to receive service from the Burfell and Sog plants and provide services to Reykjavík and the existing fertilizer plant.

The Burfell Project will also include an initial storage development at the natural lake, Thorisvatn, located about 35 kilometers northeast of the powerhouse, to provide water as required to assist in sluicing ice past the diversion from the Thjorsa and to augment low flows in the river.

Ancillary features of the Burfell Project will include access roads, operators village, and the reservoir features for ice control.

The Burfell Project is described more fully in Chapter I of the main body of this Report. Details are presented for the Thjorsa diversion features in Chapter II; for the direct power features in Chapter III; for the transmission features in Chapter IV; and for the Thorisvatn initial storage in Chapter IX. Details of construction are presented in Chapter V. Details of Project costs are presented in Chapter VI. The estimates of power and energy generation, together with the bases therefor, are discussed in Chapter VII. Ice problems are presented in a general way in Chapter VIII. Previous reports prepared by our company are summarized in Appendix A. Appendix B presents alternative schedulings for the Burfell Project to that presented in the main body of this Report.

Staged Construction

The construction of the Burfell Project as discussed in the main body of this Report will be staged to fit the load growth, which is controlled largely by almost sudden increments of the proposed smelter. Stage I will provide three generating units of 35 MW each, for a total of 105 MW, slightly ahead of full operation of the first potline of the smelter which has a firm demand of 60 MW. Generation will begin with the first unit near the end of 1968, and the first three units are scheduled for full operation by April, 1969, in advance of full demand of the first potline now scheduled for mid-1969. A single unit will be added in Stage II about the end of the 1971 slightly in advance of the full operation of the first one-half of the second potline which has a firm demand of 30 MW. Another unit will be added in Stage III about the end of 1973, primarily to meet the normal load growth of Southwest Iceland. The last unit will be installed in Stage IV about the end of 1974 in advance of the 30 MW firm demand of the last half of the second smelter potline. Transmission facilities will be constructed apace with the installation of generating units.

Much of the Burfell Project will be constructed in Stage I adequate to serve the ultimate six-unit installation. The direct power features will be complete except for the last three generating units (and their auxiliaries) which will be added as single units in each of the subsequent three Stages. The Thjorsa diversion features in Stage I will be substantially complete, although constructed with headwater about two meters below the ultimate normal level. The ultimate normal level will be achieved in Stage III with a raising of the spillway, installation of gates thereon, enlargement of the canal leading to the regulating pond, and raising of some of the control dikes. This deferred construction is possible because flow regulation at the point of diversion is not required to supply the first four generating units, but is required thereafter. The initial storage at Thorisvatn will be provided in Stage III. The transmission features will be complete in Stage I except for switchyard expansions necessary to meet the later increases in generation and in load. These expansions will be made as appropriate in each of the last three Stages. Certain combinations of the four Stages of construction of the Burfell Project may be feasible from the construction and financing standpoints.

Details of the staged construction are discussed generally throughout the main body of this Report, and in Appendix B for alternative schedulings without an aluminium smelter, and also with the smelter constructed in two complete potline increments.

Power and Energy

Burfell is a run-of-river Project depending for its power and energy production on the useful head developed and the water available. The gross head is fairly constant, subject nearly all the time to less than about a two percent variation. Hydraulic losses in the water conductors are also relatively small. The average flow in the Thjorsa at the point of diversion has been estimated at 338 cubic meters per second (cms). This is greatly in excess of the maximum turbine capacity for six units. The Thjorsa is not subject to the extreme variations in flow characteristics of most rivers which have been developed for power. This relative uniformity of flow is the result of generally favorable physical factors. Nevertheless, there are some variations in the flow. The relation between available flow and plant rated flow capacity is as follows:

Number of units installed	Station Rated Flow Capacity-cms	Percent of Time Station Rated Flow Not Available
2	75	0.0
3	112	0.2
4	150	3.5
5	188	13.8
6	224	25.0

The primary energy production of the Burfell Project for each level of installation has been considered as that produced from the flow available up to the station rated flow capacity listed above. On this basis the average annual primary energy delivered to the Geithâls substation is estimated as follows:

Number of units installed	Annual Primary Energy - GWh.
2	600
3	900
4	1190
5	1480
6	1720

Secondary energy which will be available for extensive periods by full-gate operation of the turbines was not evaluated.

Energy requirements for load may, at times, exceed the available supply from the Southwest Iceland Power Supply System because of: (1) inadequate total available installed capacity; (2) reduction in water supply for power at Burfell because of ice problems either restricting diversion capacity or requiring dominant use to assist in passing floating ice; (3) transmission and other outages; or (4) the deficiencies in available flow noted above. Thorisvatn initial storage is included beginning with the five-unit installation of Stage III to provide stored surplus water to alleviate ice problems. These energy deficiencies will need to be offset by generation from reserve stations. 33 MW of capacity will be available in existing stations which will be in a reserve status. Any new generation required for reserve purposes is beyond the scope of this Report. The use of reserve stations to the extent required to firm the energy output at Burfell is considered far more economical than providing upstream storage to offset the flow deficiencies in the Thjorsa noted above.

The peaking power which the Burfell Project, as proposed in this Report, can deliver to the Geithåls receiving substation has been estimated as follows:

Number of Units Installed	Delivered Peaking Capability-MW
2	75
3	111
4	148
5	183
6	220

The above peaking capabilities are not expected to be affected to any appreciable extent by either high or low flow or ice conditions in the Thjorsa or Fossa. Variations in System load demands are expected to permit power deliveries from the System to the smelter to exceed somewhat the firm demands thereof referred to above.

The hydroelectric generation of the Burfell Project is discussed in detail in Chapter VII.

Project Costs

Cost estimates were prepared by us for each of the four Stages of the Burfell Project presented in the main body of this Report. The estimates were made for the total construction cost and, cumulatively, for the initial annual operation and maintenance expense for each Stage. Capital and annual costs were not estimated for elements dependent on financing terms or administrative policies, such as interest during construction, capitalized reserves and working capital, depreciation or amortization, water rights values, taxes, insurance, profit, sinking fund reserves, and the like. The cost estimates are discussed in detail in Chapter VI.

The estimates of total construction costs are based on construction and permanent equipment supply dominantly by contracts involving free world competitive bidding. Each Stage was considered to be constructed separately. The cost estimates are considered good for the year 1965, barring any major increase in Icelandic labor rates, or any applicable currency devaluation. The total estimated construction cost of each Stage includes the direct construction cost, contingencies, and engineering and overhead costs. The Stage I estimate includes previous expenditures by the Government of Iceland chargeable to the Project. The estimates for the other three Stages each include an allowance attributable to their deferred construction.

The estimated total construction costs in U. S. dollars for the Burfell Project scheduled by Stages to meet smelter loads are as follows:

Stage	Domestic Currency Requirements	Foreign Currency Requirements	Total
I	$ 11,500,000	$ 16,874,000	$ 28,374,000
II	386,000	1,232,000	1,618,000
III	2,308,000	3,547,000	5,855,000
IV	311,000	1,095,000	1,406,000
Totals	$ 14,515,000	$ 22,748,000	$ 37,253,000

Estimates were made of the disbursements of the construction costs by years for the several schedulings of the Project presented in this Report. The disbursements are estimated on the basis of actual fund requirements and will lag commitments somewhat. The assumption was made that there would be a ten percent withholdings on construction and equipment supply contracts, and that these withholdings would not be released until after contract completion and satisfactory equipment performance.

The total disbursement requirements by years for each of the three construction schedules presented in this Report are estimated to the nearest 0.1 million U. S. dollars as follows:

A. Project Scheduled For One Initial Potline Plus Two One-half Potline Increments (Main Body of Report)

Year:	1964	1965	1966	1967	1968	1969	1970	1971
Requirements:	1.0	1.2	3.5	10.5	9.4	2.8	0.7	0.8
Year:	1972	1973	1974	1975	Total			
Requirements:	2.9	3.0	1.4	0.1	37.3			

B. Project Scheduled For One Initial Potline Plus One Full Potline Three Years Later (Appendix B of Report)

Year:	1964	1965	1966	1967	1968	1969	1970	1971
Requirements:	1.0	1.2	3.5	10.5	9.4	2.8	1.3	4.4
Year:	1972	1973	Total					
Requirements:	2.3	0.9	37.3					

C. Project Without Smelter Loads (Appendix B of Report)

Year:	1964	1965	1966	1967	1968	1969	1970	1971
Requirements:	1.0	1.2	4.2	7.9	5.3	1.8	0.0	0.0
Year:	1972	1973	1974	1975	1976	1977	1978	
Requirements:	0.0	0.0	1.0	1.7	0.3	1.2	2.4	
Year:	1979	1980	1981	1982	1983	1984	Total	
Requirements:	0.5	2.0	3.8	1.2	1.1	0.1	36.7	

The estimate for 1964 represents all expenditures prior to the beginning of 1965.

The estimated annual operation and maintenance (O&M) expense in U. S. dollars, based on present cost levels, as units are installed in the Burfell Project is as follows:

Number of Units installed	Annual O&M Expense
2	$ 280,000
3	315,000
4	350,000
5	385,000
6	420,000

The above costs may increase in future years, dependent on the effect of any inflation.

Summary and Conclusions

The studies summarized in this Definite Project Report have shown that the Burfell Project is feasible technically and presents no unusual construction problems. Further, construction by the Stages proposed, or appropriate combinations thereof, is feasible and involves no replacement of earlier constructed facilities. On the basis of the expected loads, Southwest Iceland should need no additional generating capacity prior to about 1975, except for reserve capacity associated with the special requirements of the proposed aluminium smelter.

We conclude on the basis of our engineering studies of hydro-electric power resources development in Iceland, which have extended over the past seven years, that the Burfell Project represents the next logical development of these resources to meet the expected loads of Southwest Iceland.

Very truly yours,

HARZA ENGINEERING COMPANY INTERNATIONAL

C. K. Willey

C. K. Willey
Vice-President

BURFELL HYDROELECTRIC PROJECT

SIX - 35 MW UNITS INSTALLED

TABULATION OF SIGNIFICANT DATA

Drainage area - square kilometers	6350
Discharge - cubic meters per second	
Maximum design flood	7750
Maximum historical	1980
Average	338
Minimum historical	72
Headwater elevation - meters above sea level.	
Maximum (at maximum design flood)	248
Normal	244.5
Minimum	243.5
Tailwater elevation - meters above sea level	
Maximum with ice jam in Thjorsa	130 ±
Normal maximum (flood in Fossa)	126.5
Normal	126.0
Minimum	125 ±
Minimum after assumed degradation in Fossa	123 ±
Diversion dam	
Crest elevation of overflow section - meters above sea level	243.75
Crest elevation of gated section - meters above sea level	242.5
Height of overflow section from foundations - meters	5.5
Diversion Dikes	
Total length - meters	5000
Maximum height from foundations - meters	30
Total volume of fill - cubic meters	840,000
Diversion, Bjarnalaekur and Approach Canals	
Total length - meters	4150
Total volume of excavation - cubic meters	1,400,000
Penstocks	
Number	2
Type: Horizontal steel lined - diameter meters	5.5 branching into 3-3.0
Concrete lined, horizontal and vertical - diameter meters	6.0
Length each Surge Tank to Powerhouse -	
horizontal leg, meters	239.0
vertical leg, meters	97.0

Powerhouse	
Type	surface indoor
Length - meters	86
Width - meters	31
Height - meters	34
Power Tunnel	
Type	arch crown, vertical sides, lined invert rest gunite lined where necessary
Diameter - meters	10
Length - meters	1040
Turbines	
Number	6
Type	Francis
Rating at 115 meters net head - metric horsepower	51,600
Discharge at rated head, full gate - cubic meters per second	40.3
Speed - revolutions per minute	300
Generators	
Number	6
Type	vertical shaft, hydraulic turbine driven
Rating - kilovolt-amperes	38,889
Power Factor	0.9
Voltage - kilovolts	13.8
Phases	three
Cycles per second	50
Speed - revolutions per minute	300
Transformers	
Number	9
Type	outdoor, single-phase, OA/FA/FOA
Bank Rating - megavolts-amperes	51.6/68.8/86
Voltage - kilovolts	13.2-230
Main transmission line	
Length - kilometers	
Burfell to Irafoss - 1 circuit	60
Irafoss to Geithals - 1 circuit	34
Geithals to Straumsvik - 2 circuits	17
Voltage - kilovolts	230
Construction	steel or wood poles
Thorisvatn Outlet Works	
Length of canal - meters	3200
Quantity of concrete - cubic meters	1225
Number and type of gates	1 - hydraulically operated slide gate 1 - emergency wheeled slide gate

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THE REPORT

Chapter I

GENERAL DESCRIPTION OF PROJECT

Introduction

The Burfell Hydroelectric Project will be located on the Thjorsa approximately 86 kilometers upstream of its mouth where the river falls about 120 meters in 13 kilometers as it circles the south end of the mountain, Burfell. The available head will be developed by a diversion north of the mountain, Burfell, into the Fossa about 2 kilometers upstream of its confluence with the Thjorsa.

This Definite Project Report is the result of studies which have continued since 1959. The studies to date have involved an unusual completeness of field investigations and analyses. The results of the previous studies have been presented in a number of reports, as are summarized in Appendix A. This Definite Project Report is based on a definite project to serve Southwest Iceland normal loads plus an aluminium smelter of one potline with a firm demand of 60 megawatts (MW), followed by additional smelter loads of 30 MW each in one-half potline increments at three-year intervals after the completion of the initial Burfell generating station. This initial generating station will consist of three units of 35 MW each, and is scheduled for completion by April 1969, with the first two units going into commercial operation somewhat earlier. Thus, power and energy will be available for incremental start-up of the first potline aimed for its full demand by mid-1969.

Two alternative schedulings of the Burfell Project are presented in Appendix B, hereto. The first presents the scheduling required to meet the full load operation of the second potline by mid-1972 plus that of the first potline by mid-1969. The second presents the scheduling required to meet the normal load growth of Southwest Iceland without an aluminium smelter.

The Burfell Project presented in the main body of this Report is based on the four Stages of construction as presented in Report No. 10 of Appendix A. These four Stages of construction are used in this current Report primarily for convenience. The unit generating size of 35 MW has been adopted. Stage I of three units totaling 105 MW is considered to be completed by April of 1969. One unit each will be added in Stages II, III, and IV, respectively. The scheduled completion dates are, in order, the ends of 1971, 1973, and 1974, but could vary a few months either way if desired at the time. The relation of these generator installations to the projected load growth, including that of the aluminium smelter, are as shown on Exhibit 11.

Stages might actually be combined. For example, it may be logical to combine Stages III and IV. Also, especially if the expansion of the smelter load is somewhat less than at three-year intervals, Stage II might be combined with Stage I. Various other combinations of the four Stages of construction presented in this Report may prove feasible.

General

The Burfell Project is located on the Thjorsa about 100 kilometers east of Reykjavik, as shown on Exhibit 1. This location in relation to cultural and other features of Southwest Iceland is shown on Exhibit 2. This Exhibit also shows access.

The Burfell Project, in the definite plan of this Report, will develop about 119 meters of gross head below elevation 244.5 at the point of diversion in the Thjorsa. The Project will consist of three principal elements:

the Thjorsa Diversion Features, the Direct Power Features, and the Transmission Features. Ancillary features associated with the Project include the Burfell Reservoir, Access Roads, and an Operators' Village. The features of the Project are described briefly below, and more fully in the Chapters which follow.

Thjorsa Diversion Features

The Thjorsa Diversion Features will consist of the Diversion Weir, Diversion Inlet, Diversion Canal, Bjarnalaekur Sluice Structure and Canal, and Dikes. The Diversion Weir extending entirely across the present channel of the Thjorsa will be a partially gated, concrete spillway structure designed to control the headwater elevation at 244.5 by regulating flows as between the spillway and diversion for power. With its gate operation it also serves to aid in sluicing ice to downstream, but at times with some interference to flows diverted for power.

The Diversion Inlet is a concrete structure with the function of excluding floating ice from entering the Diversion Canal and beyond, where same might interfere with power operations. The structure provides entry ports as deep as is feasible in a shear wall designed to guide floating ice to the spillway.

The Bjarnalaekur Canal takes advantage of the low level of the Bjarnalaekur to provide a means of sluicing ice and silt with a relatively small amount of flow. It also permits placing the ports at low level in the Diversion Inlet. It consists of an excavated Canal with a concrete control structure at the upstream end, and located at the right end of the Diversion Weir to form a junction with the Diversion Inlet. The Bjarnalaekur Sluice Structure is equipped with both undersluice and crest gates.

The Left Bank Dike is a low fill structure extending from the left end of the Diversion Weir eastward to high ground at the Hekla lava front. It is designed to prevent flood flows or flows diverted by upstream ice jams from passing to the Ytri-Ranga or around the Diversion Weir to the Thjorsa downstream thereof.

The Right Bank Dike will also be a low fill structure connecting northward from the Diversion Inlet to high ground on the right bank of the Thjorsa. It is designed to exclude ice and silt-bearing flood waters from entering the Bjarnalaekur Pond and also to permit unwatering of the Pond.

The Diversion Canal will be excavated to convey water diverted from the Thjorsa through the Diversion Inlet to the Bjarnalaekur Pond. The Bjarnalaekur Pond will permit regulation of flows diverted for power, and also serve as a reservoir for silt storage. The Pond is retained on the left side by the Bjarnalaekur Dike, a fill structure connecting from the left end of the Diversion Inlet to high ground on the right bank of the Bjarnalaekur. A concrete control structure will be located at the Bjarnalaekur to permit the release of water from the Pond either for sluicing ice and silt entering that stream from the Bjarnalaekur Canal, or for unwatering the Pond. Bulkheads would be placed in the ports of the Diversion Inlet before the Pond is unwatered. The Samsstadaklif Dike, a low fill structure, will retain the Pond at the west end where the natural ground level is lower than the planned pool level.

Direct Power Features

The Direct Power Features will consist of water conductors between the Bjarnalaekur Pond and the Fossa, and of the Powerhouse. The water conductors will consist of the Approach Canal, Samsstadaklif Sluiceway, Power Intake, Power Tunnel, Surge Tanks, Penstocks, and Tailrace. The Approach Canal will be excavated from the Bjarnalaekur Pond to the Power Intake at the upstream end of the Power Tunnel. A low concrete gravity wall is required to retain water in the Canal on the left side between the Samsstadaklif Dike and the Power Intake.

The Samsstadaklif Sluiceway will be excavated from the left end of the Power Intake southward to the topographic break on the south side of Samsstadamuli. A concrete control structure with crest gate is provided at the upstream end. The Sluiceway is designed to provide a means of sluicing ice and debris from the Approach Canal, and discharging same to the Fossa via a small stream.

The Power Intake is a concrete structure at the upstream end of the Power Tunnel designed to provide low hydraulic losses. It will contain trashracks and closure bulkheads handled by hoists located in a control house surmounting the Intake structure.

The Power Tunnel will extend from the Intake to the Penstock bifurcation just ahead of the Surge Tanks. It will have full concrete lining only where steel supports may be required. The entire floor, however, will be concrete lined to provide sealing, and this will also improve the hydraulic efficiency. The crown and side walls will be gunited in jointed zones in order to reduce leakage.

Two Penstocks are provided between the Power Tunnel and the turbine spiral cases, each to serve 3 units after trifurcating just upstream of the Powerhouse. The initial section of each Penstock represents a short continuation of the Power Tunnel to beyond the Surge Tank before dropping vertically to a horizontal leg at distributor level. The Penstocks will be concrete lined throughout, with plate steel lining additionally in the downstream portion where the rock cover is inadequate.

A Surge Tank is located in each Penstock within the high level horizontal leg and the two Surge Tanks will be interconnected by a gallery. Each will be in rock excavation concrete lined up to the ground surface and continue upward as a concrete structure to the required top level. Each Surge Tank will contain an emergency closure gate operated by a hoist located in a reinforced concrete house surmounting the top of the Surge Tank structure.

The Tailrace will be excavated from the mouth of the draft tubes of the Powerhouse to the Fossa. When the Thjorsa waters are diverted through the Powerhouse it is expected that the bed level of the Fossa will be lowered by as much as 2 meters or more at its junction with the Tailrace. In effect, the downstream 2 kilometers of the Fossa will become a part of the Tailrace, but artificial deepening is not contemplated.

The Powerhouse will be of the surface indoor type with a concrete substructure and a steel frame superstructure. The superstructure will be enclosed with reinforced concrete and metal sandwich panels. The Powerhouse will house the main generating equipment and will consist of an erection bay and 6 unit bays. The turbines will be of the vertical Francis type with steel spiral cases, and each will drive an alternating current generator. Each turbine will be protected by a butterfly valve positioned just ahead of the spiral case. The Powerhouse will contain miscellaneous mechanical and accessory electrical equipment and service systems conventional for a powerhouse of this type.

Transmission Features

The Transmission Features will provide conveyance for the power and energy generated by the Burfell Power Facilities to the Reykjavik and Straumsvik load centers. The Sending Substation at Burfell will be connected to a Receiving Substation at Geithals by a single transmission line with an emergency intertie provided at Irafoss. Two high voltage transmission lines will extend from Geithals to a Receiving Substation at Straumsvik to provide power and energy to the aluminium smelter. The above facilities are for a nominal voltage of 230 kilovolts (Kv). In addition, the Geithals Receiving Substation will include a 138 Kv switching station to interconnect with 138 Kv services to Korpulfsstadir and Ellidaar and from Irafoss. Each Substation will contain essential switching, transformation equipment, and structures.

The main power transformers at the Burfell Powerhouse will consist of banks of three single-phase transformers, each serving a pair of generating units. The transformers will be located on the deck at the upstream side of the Powerhouse superstructure and will be connected by overhead high voltage lines to the Burfell Sending Substation. A 69 Kv service will be provided at Burfell to tie to a transmission line extending to Hvolsvollur but the transmission line is not a part of the Burfell Project.

Burfell Reservoir

The actual reservoir behind the Thjorsa Diversion Weir will be relatively very small because of the steep grade of the river and the small increase in normal water levels. The ice problem on the river, in major part, requires the inclusion of construction features related thereto. A low dike of fill construction will be located paralleling the right bank of the river upstream of the Diversion Features and designed to prevent water diverted by ice jams or high flood stages from entering the Fossa through the Rauda Gap. Such diversion might result in aggradation of the Tailrace from the Powerhouse.

There are several braided reaches in the vicinity of the confluence of the Tungnaa and the Thjorsa. The enlarged surface area of the two rivers provided by these braided reaches results in excessive water surface area which, in turn, contributes to the formation of sludge ice. It is now proposed to canalize some of these reaches by means of low rock groins to restrict each river to fewer channels. The design of these canalization features has not been definitely established; nevertheless an allowance is made for same in the cost estimates.

Inasmuch as blowing snow contributes to sludge ice during cold spells, snow fences will be provided on both sides of the Thjorsa for several kilometers upstream from the Diversion Features.

Surveillance of headwater levels and ice conditions at the Diversion

Weir and Inlet will be required from the control room of the Powerhouse. Accordingly, automatic water stage indicators and transmitters will be provided at these structures. It is also planned to include a closed circuit television system to permit visual observation, especially of ice conditions. Television cameras will be located on poles to give full coverage by remote control operation of all important areas. Floodlights will be installed coaxially with the cameras. The powerhouse operator will then be able to view conditions at the site of the Diversion structures. A microwave system will permit similar viewing at the Reykjavik dispatching center.

Access Roads and Operators' Village

The main access to the Burfell Project will be by road eastward from Selfoss on the north side of the Thjorsa. Improvement of existing roads and trails is required generally eastward from near Urridafoss, and several new bridges are required, notably across the Sanda and Fossa.

The improvement of the main Access Road on the north side of the Thjorsa was commenced in 1964.

Access on the east side of the river to the Project area will require some improvement of existing trails from the vicinity of Skard.

Access Roads within the Project area will interconnect the various Project features and will tie to the main Access Road.

An Operators' Village nearby the powerhouse will be provided for the housing of the operating personnel. Much of this Village will be built early in the construction program to provide housing for engineering personnel during the construction period.

Thorisvatn Initial Storage

The addition of generating capacity at Burfell beyond the first four units will require stored waters to firm up the low flows for power production and also to provide supplemental water to assist in sluicing ice over the Diversion Weir and over the Canal Sluice Structure. An initial development is proposed to use water from the natural lake, Thorisvatn, as is discussed more fully in Appendix D of Volume II of Report No. 5 (Appendix A), and in Chapter IX.

A diversion canal will be excavated through a low divide at the southwest end of the lake. This canal will be provided with a concrete control structure containing a remotely controlled gated undersluice. Water as required and available will be released to enter the Tungnaa upstream of the Project.

Another small storage may be developed on the Fossa upstream of Haifoss in the natural basin of Fossolduver. A fill dam will be required to retain the reservoir. Water would be diverted by a tunnel extending to near the headwaters of the Rauda, thence by an open canal to the Thjorsa. The Rauda dike discussed above would serve to prevent the diverted waters re-entering the Fossa. A development of this storage in this fashion has not been studied in detail; however, it is apparent that the facilities required for storage and diversion could be readily adapted for power generation as a possible next step in the development of the water resources of the area.

Construction by Stages

The Project as discussed above represents the ultimate development of the definite Project. However, construction is planned to proceed by Stages in order to provide generating units in conformity with the demands of the load, as presented above.

The construction of the Thjorsa Diversion Features in Stage I will be as follows: The Left Bank Dike, Diversion Inlet and Samsstadaklif Dike will be completed in their entirety. The Bjarnalaekur Sluiceway and Canal will be completed except for the crest gates and their concrete embedment. Only the concrete base of the Diversion Weir will be built, although the gate piers will be constructed to a somewhat higher level and the left wing and gravity walls will be complete in order to accommodate the Left Bank Dike. The Bjarnalaekur Dike will be constructed only high enough to contain the initial level of the Bjarnalaekur Pond. The excavation of the Diversion Canal will be only adequate to meet design flow velocities for four units, plus some opening up in front of the Diversion Inlet.

The completion of the Diversion Features will be accomplished in Stage III.

The Burfell Reservoir features will be completed in Stage I.

The water conductors of the Direct Power Features will be completed in Stage I, except for the emergency gate and hoist in the left Surge Tank which will be installed with the fourth generating unit in Stage II. The Powerhouse will be completed in Stage I, except for the installation of the last three generating units, guard valves, and associated electrical and mechanical equipment. This installation will be by single units in Stages II, III, and IV, respectively.

Two banks of main power transformers will be provided at the Burfell Powerhouse in Stage I, with the third bank added in Stage III. The Burfell Sending Substation will be complete in Stage I, except for one bay which will be added to Stage III to accommodate the last bank of main power transformers.

The Irafoss intertie will be accomplished in Stage I.

The 230 Kv portion of the Geithals Receiving Substation will be complete in Stage I, except that a breaker will be added in the bay serving the reserve auto-transformer and also for another bay and breaker to serve for transfer, all of which will be included in Stage III. Also a bay with breaker will be added in Stage IV to accommodate the auto-transformer removed from the Irafoss Intertie. The 132 Kv portion of the Geithals Substation will be complete in Stage I, except for two bays with breakers which will be added in Stage III, one to serve for transfer and one to serve for an additional transmission line to Ellidaar. Also, in Stage IV, a bay will be added to connect with the auto-transformer added in the 230 Kv portion.

That portion of the Straumsvik Receiving Substation representing a part of the Burfell Project will be complete in Stage I.

The Approach Roads will be substantially complete in Stage I, but some rebuilding is considered likely in Stage III, along with improved access to the left side of the Thjorsa in the vicinity of the Diversion Weir and on to Thorisvatn. The construction of Thorisvatn Initial Storage will be in Stage III.

The Operators' Village will be completed substantially in Stage I, but some additions are included for each of the three subsequent Stages.

Chapter II

THJORSA DIVERSION FEATURES

General

The Thjorsa Diversion Features of the Burfell Project have the primary function of diverting water for power from the Thjorsa and regulating same in the Bjarnalaekur Pond. The Features will consist of the Diversion Weir, Bjarnalaekur Sluice Structure and Canal, Diversion Inlet, Diversion Canal, Bjarnalaekur Dike, Samsstadaklif Dike, Left Bank Dike, and Right Bank Dike. These Features are shown in plan on Exhibit 4. Detailed plans and sections are shown on Exhibits 5 and 6.

Thjorsa Diversion Weir

The Diversion Weir will have the function of creating head for diverting water for power from the river into the Pond. It will also serve as a spillway to discharge surplus water and floating ice to downstream. Details of the Diversion Weir are shown in plan and sections on Exhibit 5. The Weir will be a concrete structure extending across the present width of the Thjorsa and will consist of two segments. The right segment, 122.4 meters long, will be a gated section; the left segment, 240 meters long, will be an overflow section surmounted by flashboards. The left pier of the overflow section will extend downstream as a training wall and will also serve to retain the

Left Bank Dike. Beyond that pier a concrete gravity wall will extend for 30 meters to provide a tie to the Left Bank Dike core.

The crest of the gated section was set at El. 242.5, or only slightly above the existing riverbed. Crest control will be by four 30 meter wide by 2 meter high fishbelly flap gates. These overflow type gates will permit the passing of floating ice with a minimum of water loss. Operation of each gate will be by a single hydraulic hoist at one end and only three piers must be wide enough to accommodate the hoists. The pier on the right will also be the left pier of the Bjarnalaekur Canal Sluice Structure. Two relatively narrow intermediate piers will be required for the installation of side seals and heating elements.

Access to the two left pier hoist-operating platforms will be by a gallery within the concrete sill, thence vertically by a shaft within each of the two piers. The gallery will also house the oil lines to the cylinders and electrical service to the heating elements and for lighting. The operating center for all gates will be in the left pier of the Bjarnalaekur Canal Sluice Structure, and operation will be by remote control from the Powerhouse.

The crest of the left overflow section beyond the gated section will be at El. 243.75. Three-quarters of a meter of timber flashboards will be required to bring the controlled level to 244.5. The gated section, together with the sluice and power discharges, will pass all floods with a frequency of less than about four years, thus only the larger floods will overtop the flashboards. Flashboards lost by overtopping or for other reasons can be replaced easily and cheaply.

The grade of the spillway apron was set at El. 239.5 for both the gated and ungated sections of the Weir. The hydraulic operation of the Diversion Weir is one of the features currently being checked by hydraulic model studies.

The Diversion Weir will be constructed principally in Stage I, and that portion required for completion, which will be constructed in Stage III, is shown by shading on the sections of Exhibit 5.

Bjarnalaekur Sluice Structure and Canal

The Bjarnalaekur Canal takes advantage of the low level of the Bjarnalaekur in relation to that of the Thjorsa to provide a means of sluicing ice and silt with a relatively small amount of flow. It also permits placing the ports at low level in the Diversion Inlet. The Bjarnalaekur Canal will be in excavation for a length of about 2 kilometers and will have a concrete control structure, the Bjarnalaekur Canal Sluice Structure, at its upstream end. The location of the Bjarnalaekur Canal is shown in plan on Exhibit 4 and in profile and section on Exhibit 6. The Bjarnalaekur Canal Sluice Structure is shown in plan and sections on Exhibit 5. The design level of the Bjarnalaekur Canal grade at the Bjarnalaekur was set at El. 225, which is about 17 meters below the natural level in the Thjorsa at the upper end of the proposed Canal. This differential provides adequate height both for a Canal grade permitting relatively high velocities and also for lowering the Diversion Inlet ports to 8 meters or more below the controlled level of the Thjorsa upstream of the Diversion Weir.

The Canal grade was set at El. 234 at the Thjorsa end. This results in an adequate thickness (3 to 4 meters) of the base of the uppermost Thjorsa lava flow as the foundation for the concrete structures in that vicinity. The Canal was set with a base width of 6 meters and a grade of 0.0048 in order to maintain the moderately high velocities over the required flow range to transport silt and ice on to the Bjarnalaekur. The resulting velocities will range between about 2.4 and 3.5 meters per second over a flow range of 25 to 100 cubic meters per second, respectively.

Recent drillings indicate that the older basalts shown on the Canal profile of Exhibit 6 will reach approximately the Canal grade about 600 meters downstream from the upstream end of the Sluice Structure and thus will provide an erosion control section at an adequate distance downstream from the point of diversion. Some erosion can be expected downstream from the control section until such time as equilibrium is achieved. This possible retrogression of the channel in the downstream portion is not expected to affect the functioning of the Canal adversely.

The discharge to the Canal will be controlled by a concrete Sluice Structure which represents the right bay of the Thjorsa Diversion Weir. This Structure is shown in plan and sections on Exhibit 5. It will contain two undersluices set at El. 231.5 grade, with control provided by two 2.5-meter square wheeled gates. Each gate will be controlled by hydraulic cylinders positioned in the gallery within the concrete mass above. These undersluices will permit some desilting from in front of the Diversion Inlet and also provide any required water for aiding in ice and silt transport within the Canal.

The section of each of the undersluices will be expanded laterally and graded upward downstream from the gate. The upward grade will extend through a concrete-paved stilling basin and terminate in a 0.5 meter high sill located 25 meters downstream of the undersluice outlet. The crest elevation of 234 for the top of this sill represents the beginning of the Canal grade. The walls of the stilling basin will be concrete-lined below the top of rock. The lining will continue on the right side of the Canal for 20 meters downstream from the end of the stilling basin. At that point the Canal is 12 meters wide and will begin to transition smoothly over a distance of 33 meters to attain its normal base width of 6 meters.

The overflow section of the Sluice Structure will have a crest width of 12 meters and a modified ogee downstream face. A 2 meter high fishbelly flap gate will provide crest control. Stop log slots will be provided in the pier faces of the Structure to permit maintenance closure of the undersluices.

The right pier of the Sluice Structure will extend to El. 250 and also serve to retain, in part, the fill of the Bjarnalaekur Dike. A sloping concrete wall, the toe of which rests on the stilling basin and canal lining, will extend as far downstream as is required to retain the Dike fill. The right pier will contain a gauge well with a stage recorder and transmitter which are part of the Burfell Reservoir features.

A forked-shaped hollow pier will be provided at the left end of the Sluiceway Structure. The right leg will provide a training wall in the downstream direction. The left leg will serve as a training wall for the first gated bay of the Diversion Weir, then extend as a separator wall to El. 244 downstream to exclude all but extreme floods of the Thjorsa from entering the Bjarnalaekur Canal. The separator wall portion will be 80 meters long and its toe will rest on the left concrete lining of the stilling basin and Canal, which lining will extend to the same terminus. The lining beneath the separator wall will be post-tensioned with steel anchors into the rock to insure the stability of the lining and wall.

The hollow center of the left pier of the Sluice Structure will provide access to the sluice gate operating gallery and to the gallery leading to those Diversion Weir piers upon which the spillway gate operating cylinders will be positioned. A bridge deck will connect the right and left Sluice Structure piers.

The Bjarnalaekur Canal will be completed in Stage I as will most of the Sluice Structure. The remainder of the Sluice Structure will be completed in Stage III, to include the installation of the crest gate, as is shown by shading on the section of Exhibit 5.

Diversion Inlet

The Diversion Inlet will have the primary function of preventing floating ice from being included in the water diverted for power. It will consist of a concrete structure located along the right bank of the

Thjorsa upstream from, and approximately at right angles to, the Diversion Weir and the Bjarnalaekur Canal Sluice Structure. The Diversion Inlet is shown in plan, section and profile on Exhibit 5. While the profile shows the four right bays as ultimate construction, it is now planned to complete all of the Diversion Inlet in Stage I.

The Diversion Inlet will consist of 12 bays. Each bay will contain a 10 meter wide by 2 meter high entry port positioned just above the floor of the structure. These ports will provide low level entry of the water diverted for power from the Thjorsa to the Diversion Canal and Pond. The entrance to the ports will be bell-mouthed for hydraulic efficiency and they will extend only through the vertical shear wall, a distance of about 1.5 meters. The ports will be provided with heating elements to prevent clogging by the adherence of anchor ice. Each port will be separated from the adjacent ones by intermediate piers. The sill elevation of the left port is set at El. 232.5 and the grade of the sill is slightly upwards towards the right end in conformity with the expected normal flow profile.

The upstream wall will be vertical on the Thjorsa side and will serve as a shear wall to guide floating sludge ice downstream for passing over the Diversion Weir or into the Bjarnalaekur Canal.

The Diversion Inlet will be surmounted by a 5 meter wide roadway which will serve principally for the positioning of any equipment which may be required to remove silt deposited either upstream or downstream of the structure. The shear wall will extend up to the deck of this roadway at El. 250 to prevent the maximum flood from entering the Bjarnalaekur Pond.

Concrete retaining walls will extend downstream from the left and right end piers in order to retain the Bjarnalaekur and Right Bank Dikes, respectively. A curved concrete guide wall will extend upstream from the right pier to form a connection with the Right Bank Dike and also to retain the fill turning area.

The Bjarnalaekur Canal will, in effect, be extended upstream with a base width of 12 meters in front of the entire Diversion Inlet structure. The riverward side slopes will be flattened in order to provide gradual velocity reductions in the diverted power flow.

Stoplog slots are provided in each bay on the Diversion Canal side of the shear wall to permit the placement of stoplogs or bulkhead gates to close each entry port if required for unwatering of the Bjarnalaekur Pond or for other maintenance reasons. Such a closure may be accomplished utilizing a truck crane positioned on the deck. Some anchorage into the rock by steel bars will be needed to provide stability of the Diversion Inlet when it is unwatered. All construction of the Diversion Inlet will be accomplished in Stage I.

Diversion Canal

The Diversion Canal will permit the conveyance of water diverted for power from the Thjorsa through the Diversion Inlet to the Bjarnalaekur Pond. The location is shown in plan on Exhibit 4, and in typical section on Exhibit 6. The location was selected to follow a low valley in the rock surface and thus minimize rock excavation. The location also permits placing as much of the Bjarnalaekur Dike as feasible on the older basalts which are far less permeable than the Thjorsa lavas.

The Canal section was established to provide a maximum average velocity of about 0.5 meters per second which is low enough to encourage the formation of an ice cover early in each winter season. The Diversion Canal requires a grade at about El. 238 near the Diversion Inlet, and a slope towards the Pond of about 0.001. This beginning elevation is 5.5 meters above the floor of the Inlet. Accordingly, it will be necessary to connect this elevation to that of the floor of the Inlet by ramping on about 5 horizontal to 1 vertical.

The ultimate base width of the Canal at grade will be about 130 meters a short distance downstream of the Diversion Inlet. The base width will be gradually narrowed to become 70 meters at a point about 300 meters downstream of the Inlet. As shown on Exhibit 5, no rock excavation is required downstream of the right few bays of the Inlet except for possibly a minor amount to smooth flow conditions. However, the overburden will be removed from downstream of these bays within the limits of the Canal.

The profile of Exhibit 6 shows a possible leakage path from the Canal into the permeable lapilli interbed underlying the uppermost Thjorsa lava flow. This interbed will be exposed by excavation entirely across the Canal and beyond on either side at a section about 500 meters downstream from the Diversion Inlet. Accordingly, this interbed exposure will be covered completely with a concrete seal extending to the sides at least as high as the normal water level in the Canal. It will also extend southward if necessary to make a tie with the core of the Bjarnalaekur Dike.

Initially in Stage I the base width of the Diversion Canal will be 90 meters immediately downstream of the Diversion Inlet. In this Stage the base width will be gradually narrowed in the next 300 meters to a constant width of 45 meters along the right side for its remaining distance. This downstream constant width section will be widened on the left side by 25 meters in Stage III, and that widening will decrease gradually upstream to zero in front of the Inlet. Much of this excavation will be accomplished under water. Also in Stage III the Canal will be widened on the right side by 40 meters immediately downstream of the Inlet. This widening will decrease gradually to zero within the next 300 meters. The Stage III widening is shown by cross-hatching on the plan of Exhibit 4.

Bjarnalaekur Dike and Outlet

The Bjarnalaekur Dike will retain the Bjarnalaekur Pond on the left side. The Bjarnalaekur Pond will serve for the regulation of flows diverted from the river for power and will also serve as a reservoir for silt which might be carried by the diverted flows. The Bjarnalaekur Dike will extend from the junction of the Diversion Inlet and Bjarnalaekur Canal Sluice Structure southwesterly to high ground on the right bank of the Bjarnalaekur, as shown in plan on Exhibit 4. This location is made to take advantage of the crest of a ridge of nearly impermeable old basalts which was found to exist by the drilling along this alignment.

The Bjarnalaekur Dike will be a fill structure constructed according to the section shown on Exhibit 6. The basic section will be of rock fill with an impervious sloping upstream core separated from the rock shells by single-zone filters both upstream and downstream.

The profile along the axis of the Dike is also shown on Exhibit 6. The geologic information indicated the danger of short path leakage from the Bjarnalaekur Pond to the Bjarnalaekur via the interbed under the uppermost Thjorsa lava flow for about 500 meters of the westerly half of the Dike. It is necessary to provide a cutoff between the top of the older basalts and the base of the impervious core of the Dike, and slurry trench construction was selected for this purpose, as shown in section on Exhibit 6. The excavated trench will be backfilled with slurry only to just above the groundwater table and a compacted impervious core will be placed in that trench between the slurry cutoff and the base of the sloping impervious core of the Dike. Grouting of the foundations will be required elsewhere under the impervious core of the Bjarnalaekur Dike as shown on the profile.

The Outlet represents a control structure located at the Bjarnalaekur. It will permit the release of water from the Pond either for sluicing ice entering that stream from the Bjarnalaekur Canal or for unwatering the Pond after bulkheads are placed to close the ports of the Diversion Inlet. It will also serve to divert the Bjarnalaekur during the construction of that portion of the Bjarnalaekur Dike.

The Outlet will consist of a 2-meter square conduit placed in an excavated trench. Control will be provided by a wheel gate located in a concrete control tower at the upstream end. Access to the tower will be by boat.

The Bjarnalaekur Dike will be constructed in Stage I, as shown in section and profile on Exhibit 6 under the designation "Initial Construction". The Dike will be completed in Stage III, as shown by "Ultimate Construction" and the cross-hatching on Exhibit 6.

Samsstadaklif Dike

The Samsstadaklif Dike will retain the Bjarnalaekur Pond at the west end where the natural ground level is less than the planned pool level. This location is shown on Exhibit 7. The Dike will be a fill structure identical in section to that of the Bjarnalaekur Dike, as shown on Exhibit 6. It will be constructed in its entirety in Stage I.

Left and Right Bank Dikes

These two Dikes were discussed in Chapter I, and more fully in Reports Nos. 7 and 8 of Appendix A. Their respective locations are shown in plan on Exhibit 4. Profiles and sections of each are shown on Exhibit 6. This Exhibit shows two different sections for the Left Bank Dike. The first kilometer portion eastward from the tie to the Diversion Weir will be identical to that of the Bjarnalaekur

Dike, except for the variable grade, and will retain the Thjorsa waters to the normal level of 244.5. Eastward from this portion water retention, in itself, is not important and a more economical section is provided. It is only necessary that the rare diversion of Thjorsa overflow waters do not produce piping velocities in leaking a small amount through this eastern portion of the Dike. The rockfill under the sand core will be selectively placed for filter effect with fine material, such as quarry spoils, to the upstream and coarser materials to the downstream.

Inasmuch as the Right Bank Dike is only required to prevent Thjorsa flood waters from carrying sediment into the Bjarnalaekur Pond, and to dewater the Pond, the Dike core is carried only to El. 246 which assures that unwatering can be accomplished (with bulkheads in the Diversion Inlet ports) during all except extreme flood periods. At the left end the core will tie to the curved concrete gravity wall extending 40 meters upstream from the Diversion Inlet. Rockfill will be placed on the downstream side of that wall in order to form a turn-around for vehicles crossing the deck of the Inlet.

The Left Bank Dike will be constructed in Stage I, while the Right Bank Dike will be built in Stage III.

Chapter III

DIRECT POWER FEATURES

General

The function of the Direct Power Features will be to convey Thjorsa water from the Bjarnalaekur Pond to the Powerhouse for the production of hydroelectric power and energy, then to discharge same to the Fossa for return to the Thjorsa. The Features will include the Powerhouse and the Water Conductors. The Water Conductors will consist of the Approach Canal, Samsstadaklif Sluiceway, Power Intake, Power Tunnel, Penstocks, Surge Tanks, and Tailrace. The Direct Power Features are shown in plan and profile on Exhibit 7.

Approach Canal

The Approach Canal will extend from within the Bjarnalaekur Pond to the Power Intake, and will be about 900 meters long. The downstream portion will be excavated in basalt; the upstream portion will be excavated in lapilli requiring flat side slopes. Steep side slopes are possible in the rock.

The hydraulic design of the Canal will provide minimum feasible hydraulic losses, maximum feasible utilization of the pondage provided, and a maximum normal velocity of about 0.5 meters per second which is low enough to encourage the formation of an ice cover early in each winter season. The Canal was proportioned to meet these criteria.

The Approach Canal is shown in plan and profile on Exhibit 7. At its beginning in the lapilli on the floor of the Bjarnalaekur Canal it will have a base width of 100 meters and a bottom grade at El. 238.0. In the next 385 meters downstream it will narrow almost uniformly to a base width of 36 meters and to a grade elevation of 232.0. Basalt makes up most of the excavated section from that point onward. The grade will be uniform in the next 150 meters to reach El. 222.5, and that elevation will be maintained for an additional 240 meters. The base width will, within this combined reach, narrow from 36 to 16 meters in 95 meters, then continue uniformly at the latter width. In the last 70 meters the base of the Canal will widen to that of the Power Intake, and the grade will drop to El. 218 immediately in front of the Intake. In general, the Canal curves in plan to the right proceeding from within the Pond to the Intake.

The surface of the rock on the left side of the Canal between the Samsstadaklif Dike and the Samsstadaklif Sluiceway Control Structure is lower than the planned pool level in two places. Concrete gravity walls to El. 249 will be provided to close these gaps. Also a grout curtain to reduce leakage will extend from the Power Intake eastward just outside the left wall of the Canal, under the concrete wall, thence under the core of the Samsstadaklif Dike.

The Approach Canal will be completed in Stage I.

Samsstadaklif Sluiceway

The Samsstadaklif Sluiceway will have the function of sluicing floating ice and debris from the Approach Canal, thus preventing it from being carried on to the turbines. A concrete gated control structure will be located on the left side of the Approach Canal immediately upstream from the Power Intake, as shown on Exhibit 7. An excavated canal, 130 meters long, will extend from the Control structure southward to the topographic break in the south side of Samsstadamuli. The water used for sluicing and its ice and debris content will cascade from the end of the canal, then follow a small brook to the Fossa.

The discharge canal downstream from the control structure will have a base width of 6 meters and a slope of 5 percent from El. 235 at the control structure. It will be entirely in basalt, thus permitting steep side slopes.

The Samsstadaklif Sluiceway Control Structure will have a concrete sill with crest at El. 240.75, incorporated with concrete facing on the wall of the Approach Canal. It will be surmounted by a 6.0 meter wide by 4.57 meter high fishbelly flapgate. The gate will be operated by a hydraulic cylinder positioned externally below the gate. The top elevation of 245.32 of the gate will be overtopped only by flows in excess of the flood of record. Heater ducts and elements will be provided to insure gate operation during freezing weather. Stop log slots are provided in the side walls upstream of the gate to permit unwatering. A concrete roadway deck resting on the concrete side walls will span the gate opening.

The Samsstadaklif Sluiceway will be completed in Stage I.

Power Intake

The Power Intake will connect the Approach Canal to the Power Tunnel. It will be designed for low hydraulic losses, and will be provided with trashracks to retain debris which might otherwise reach the turbines. The location is shown on Exhibit 7.

The Power Intake will be a concrete structure extending from the Approach Canal grade of 218.0 to the deck level of El. 249.0. It will contain three bays, each 6 meters wide as far downstream as the gate slots, separated by intermediate piers. The gate sill is set at El. 222.0 which represents the beginning grade of the Power Tunnel. There is thus provided a 4 meter deep rock trap upstream of the gate sill. The water passages downstream of the gate slots will transition smoothly over 19 meters to the bore of the Tunnel. The downstream 15 meters of this transition will be in tunnel. The gate openings will be 11.5 meters high, and a concrete roof for the water passages will be provided downstream of the slots.

A concrete curtain wall will be continuous above El. 238.5 across the upstream face of the Intake. It will (1) serve as a shear wall to aid in diverting ice to the Samsstadaklif Sluice, (2) keep sheet ice away from the bulkheads, (3) keep the intakes and guides warmer during periods of frost, and (4) provide a stationary volume of water where bubbles from the air bubbler system would be effective in preventing freezing of the bulkhead gates.

The gate slots will serve both for the trashracks and the bulkhead gates. Normally the trashracks will be in position in all three bays. They will have a bar spacing of 9 centimeters, with 7.5 centimeter openings. Six sections are provided, two for each bay. Heating will be provided with the gate guides to prevent freezing.

Steel bulkheads will be provided for normal unwatering of the Power Tunnel. They would be placed ahead of the water passages in the same slots as the trashracks, with the latter removed, and 6 sections will be provided, two for each bay. Normally, the bulkheads will serve as trashrack extensions, forming a flush surface above the trashracks, but separated therefrom by insulation. Three bulkhead storage slots will be provided in the upper portion of the Intake, one above each water passage, downstream of the trashrack slots. Their use will facilitate interchange of bulkhead gates and trashracks.

A concrete gate house will extend above the deck of the Power Intake. A bridge crane will be provided in the gate house for servicing the trashracks as well as the bulkheads. All openings in the floor of the gate house will normally be covered with gratings. A balcony at deck level will be provided along the upstream face of the gate house.

The Power Intake will be completed in Stage I.

Power Tunnel

The Power Tunnel will extend 1040 meters from the Power Intake to the Penstock bifurcation. The excavation will be 10 meters wide by 10 meters high, with the upper one-half being a half-circle. The floor will be level across, and the lower 5 meters of the side walls will be vertical. The section was chosen in consideration of the vertical and horizontal jointing of the basalt through which much of the Tunnel will be driven. The location of the Power Tunnel is shown in plan and profile on Exhibit 7.

The invert elevation of the Tunnel upstream will be 222 and downstream will be 214, resulting in a grade of 0.0077.

Full concrete lining will be provided only where steel supports may be required. Frequent use of grouted rock bolts is expected throughout the Tunnel. A 10 centimeter thick concrete paving will be provided on the invert, principally to seal the vertical joints of the basalt against leakage. In otherwise unlined sections, the walls and crown of the Tunnel will be gunited in severely jointed or fractured zones; also to seal leakage. Additional sealing is expected from the fine silt carried by the Thjorsa waters.

The Power Tunnel will be completed in Stage I.

Penstocks

Two main Penstocks will be provided beyond the downstream end of the Power Tunnel. Each will serve three turbines after trifurcating just ahead of the spiral cases. After the bifurcation from the Power Tunnel, the Penstocks will extend in parallel fashion at a distance of 36 meters as far as the trifurcations. The right Penstock will be tangent with the Power Tunnel. Each Penstock will extend nearly horizontally as an extension of the Power Tunnel grade through the bifurcation to just beyond the Surge Tank, then turn vertically down to a final horizontal leg at the distributor level of 120 meters. The location of the Penstocks is shown in plan and profile on Exhibit 7.

The Penstocks will be of circular section and concrete lined, with steel lining additionally through the downstream 145 meters where the rock cover is inadequate for reinforced concrete alone. Reinforcement will be required except where the steel lining is provided. Exceptions to the circular section of the Penstocks occur in the bifurcation and for 7 meters upstream and downstream of the square emergency closure gate openings located below each Surge Tank, where transitions are provided.

Each Penstock will be 6 meters in diameter from the end of the bifurcation (except as noted above in transitions) as far as 10 meters from the upstream end of the steel lining. This 10-meter section will represent a transition to the 5.5 meter diameter of the steel-lined section upstream of the trifurcation. After trifurcating, the steel Penstock of each individual unit will be 3 meters in diameter. The center leg of each trifurcation will be over-excavated to permit entry of the 5.5 meter diameter steel cans and trifurcation sections during erection.

The Penstocks will be completed in Stage I.

Surge Tanks

A restricted orifice type Surge Tank is provided for each of the two main Penstocks to limit and suppress surges and to provide the initial water for load pick-up as well as temporary storage during load rejection. Load rejection was based on loss of full load by all 6 units during maximum flood conditions. Load demand was based on 3 units at full load to 6 units at full load with minimum headwater. The Surge Tanks will be located immediately downstream of the bifurcation as shown in plan and profile on Exhibit 7.

Each Surge Tank, 13 meters in diameter, will extend from El. 233 to El. 261 and be of concrete construction. That portion below top of rock will be excavated in basalt, then concrete lined. A concrete-lined orifice will connect each Penstock to its Surge Tank. A 4-meter diameter concrete-lined conduit will connect the two Surge Tanks just above the bottom grade of El. 233.

Each Surge Tank will also serve as an emergency gate chamber. Gate guides will extend from the Penstock grade to the top of the Surge Tanks. A vertical-lift wheeled gate of steel construction will be provided in each chamber to shut off the flow to the turbines of the three units on its Penstock in case of emergency. The normal position of each gate will be just above the top of its water passage, and it will be held in this position by its hoist subject to immediate closure against flow. Normal closure will be under balanced head. The hoist will be positioned in a concrete gatehouse surmounting each Surge Tank.

The Surge Tanks will be completed in Stage I, except for the second emergency gate and its hoist which will be installed with the fourth generating unit in Stage II. A bulkhead will be installed in the water passage during Stage I, then removed when the emergency gate is added.

Tailrace

The Tailrace will convey the turbine discharge from the end of the draft tubes to the Fossa, and will be entirely in excavation. Its length will be about 125 meters, as shown in plan and profile on Exhibit 7. The bottom grade will be nearly uniform upward from the bottom of the draft tubes to the bed of the Fossa.

After the Thjorsa waters are diverted through the Powerhouse to the Fossa some degradation is expected in the bed of that river; possibly as much as 2 meters. Thus, the downstream 2 kilometers of the Fossa may be considered as an extension of the Tailrace. No artificial deepening of the bed of the Fossa is contemplated as a part of the Burfell Project. However, same may be justified economically after equilibrium is achieved from the completed 6-unit Burfell Powerhouse.

Powerhouse and Equipment

The Powerhouse will house the main generating equipment and auxiliaries. It will be of the surface indoor type and located at the base of the west end of Samsstadamuli, as shown in plan and profile on Exhibit 7. The structure overall will be about 30 meters wide and 86 meters long.

The Powerhouse will have a concrete substructure founded on sound pillow lava. The superstructure will have a structural steel rigid frame above El. 132 and will be enclosed with concrete panels on the upstream side and metal sandwich panels, primarily, on the downstream side and on the end walls. The roof will consist of steel roof decking, supported on purlins, with a non-combustible vapor barrier and rigid insulation, and 4-ply built-up roofing with gravel surfacing. A transverse section and a longitudinal section through the erection bay and three right units are shown on Exhibit 8.

The Powerhouse substructure will have three floor levels; the turbine floor at El. 122.3, the generator floor at El. 126.8, and the erection bay floor at El. 132.0. The first two include portions located upstream of the main machine hall. A main lobby with lavatories is located at the erection bay level upstream of the erection platform and at the north end of the Powerhouse. A longitudinal piping gallery will be downstream of the turbines at El. 117.3. Access stairs, but no elevator (lift) are provided between floors at convenient locations.

Electrical storage batteries, lubricating oil storage, sewage treatment, station switchgear and cable gallery, excitation equipment, station service transformers, and air compressors will be on the turbine floor level. The control room, offices and files, lavatories, kitchen, ventilation and air conditioning room, locker and shower room, machine shop, and potable water storage room will be on the generator floor level. The erection bay equipment door, 4 meters by 6 meters, and the lobby entrance will be in the north wall of the Powerhouse.

The spiral cases will be of steel embedded in concrete and will have circular sections. Direction of rotation of the units as viewed from above will be clockwise. The draft tubes will be symmetrical and formed in reinforced concrete. A draft tube deck will be provided at El. 132.0. The deck will be used to carry a light gantry crane for handling the bulkhead type draft tube gate. Only one gate is needed for unwatering a single unit since the draft tube will not have a splitter pier. Storage will be in one of the gate guides. The draft tube deck will be wide enough for single lane traffic.

A sump will be provided to collect the Powerhouse drainage. It will contain the sump pumps and also the unit unwatering pumps. A main power transformer deck will be provided along the east side of the superstructure at El. 132. The deck will be wide enough to permit a transformer to be moved past the other transformers to the erection bay. The deck will include a trough for the temporary storage of transformer oil which might leak.

The Powerhouse electrical and mechanical equipment will include turbines and governors; generators; such miscellaneous mechanical equipment as valves, gates, cranes, pumps, heating and ventilating system, compressed air system, raw and potable water systems, sanitary system, fire protection systems, and drainage and unwatering systems; such accessory electrical equipment as low tension power cable, low tension switchgear, station service equipment, d.c. power supply, emergency diesel-generator sets, control and protection equipment; and such other equipment as is normally associated with a powerhouse of this magnitude. The Powerhouse will house all of this equipment except the 300 Kva emergency diesel-generator set which will be separately housed at the Burfell Sending Substation. Greater detail is presented below with respect to the main equipment.

The six hydraulic turbines will be of the vertical-shaft, single-runner Francis type with plate steel spiral cases and elbow type draft tubes. Each turbine will be rated to develop 51,600 metric horsepower at a rated net head of 115.0 meters. The full-gate turbine discharge at rated head is expected to be 40.3 cubic meters per second (cms). The speed was selected at 300 rpm. The turbine distributor centerline is set at El. 120.0 meters above sea level.

The turbines will be regulated by individual speed governing systems. Each governor will be of the cabinet actuator type with the main equipment located on the generator room floor.

Turbine inlet valves are required for shut-off purposes, in addition to the head gates, to permit shutting off individual turbines on the common Penstock for maintenance or other purposes. A butterfly valve with an inside diameter of 3 meters, located within the Powerhouse, will connect each unit Penstock with each turbine spiral case. A Dresser coupling will be provided downstream of each valve. The butterfly valve will be operated hydraulically by a high pressure oil system.

Each generator will be of the vertical-shaft type, driven by its Francis type turbine, and provided with direct-connected main and pilot exciters. Each will be air-cooled, with a closed cooling system using air to water heat exchangers. Each generator will be rated 38,889 Kva at 60°C rise, 0.9 power factor, 13.8 Kv, three phase, 50 cycle, 300 rpm. Each will feed its step-up transformers through metal-clad 13.8 Kv air circuit breakers. The generator leads will be 15 Kv metal-enclosed bus duct of the non-segregated-phase type, with current carrying capacity of 2,000 amperes.

The two station service transformers will be fed from Units 1 and 3, and will supply 230/400 volt, 3 phase, 50 cycle power for the station auxiliaries. They will also be connected to be fed from the main power transformers, even with the generating units not in operation. The station service switchgear will also be fed from the emergency diesel-generator. The station service will also provide electrical service for the emergency gate house, Power Intake, and Thjorsa Diversion Features. This 3-phase service will be over an 11 Kv open wire line on wood poles fed through a 150 Kva transformer located at the Powerhouse.

The raw water cooling system for the generator air coolers, bearings, and air compressor aftercooler will be a closed circuit type consisting of storage tanks, circulating pumps, heat exchangers, and wells, with all except the wells located within the Powerhouse. The wells will be used to supply clean make-up water to the closed cooling systems and also potable water. Raw water from the Penstocks will be run through the heat exchangers under headwater pressure to cool the circulating water, then discharged to tailwater.

The Powerhouse Crane will be an electrically-operated, overhead travelling bridge crane. Two trolleys will be provided with each trolley having one 70-metric ton main hoist and one 15-metric ton auxiliary hoist. The crane runway, supported on the superstructure steel frame, will extend over the entire length of the Powerhouse.

Staged Construction

The Direct Power Features will be completed in Stage I, except for installation of the last three generating units and associated equipment which will be installed by individual units in the last three Stages. The only civil engineering work associated with these subsequent installations is the concrete embedment of each spiral case, the removal of the bulkhead in the left main Penstock, together with the installation of the emergency gate and hoist with the addition of Unit 4 in Stage II, and the removal of draft tube gates and of dished head bulkheads from the individual Penstocks as the last three units are each installed in their respective Stages. These gates and bulkheads are required to assist in keeping the vacant bays from being flooded and will be provided in Stage I.

Nearly all of the miscellaneous powerhouse equipment and accessory electrical equipment will be provided in Stage I. Only that specifically associated with individual units will be added as appropriate in the subsequent three Stages.

Chapter IV

TRANSMISSION FEATURES

General

The Transmission Features will provide conveyance for the power and energy generated by the Burfell generating facilities to the Reykjavik and Straumsvik load centers. The Features will include the Burfell Step-up Substation, the Burfell-Irafoss Transmission Line, the Irafoss Intertie, the Irafoss-Geithals Transmission Line, the Geithals Receiving Substation, the Geithals-Straumsvik Transmission Lines, and the Straumsvik Receiving Substation. The location of the Transmission Features is shown in plan on Exhibit 2. A one-line diagram is included as Exhibit 9.

Burfell Step-up Substation

The main power transformers at the Burfell Powerhouse will consist of banks of three single phase transformers, each serving a pair of generating units. The transformers will be located on the deck at the upstream side of the Powerhouse. Each bank of transformers will be rated 51.6/68.8/86 MVA. The transformers will be connected by overhead 230 Kv transmission lines to the Burfell Sending Substation located about 300 meters to the south of the Powerhouse.

The Burfell Step-up Substation will be of double bus arrangement with a main bus and transfer bus, and will include 5 bays. Each of the three transformer banks will be connected through a power circuit breaker to the main bus. The main and transfer buses will be connected through a transfer breaker and a line breaker, the latter serving the 230 Kv outgoing transmission line to Irafoss. A 69 Kv service will be provided at Burfell to tie to a transmission line extending to Hvolsvollur, but the transmission line is not a part of the Burfell Project. The 69 Kv circuit will be fed through a three-phase 13.2-11-69 Kv transformer rated 20 MVA, directly connected to the main leads of Unit 2.

The Stage I construction at the Burfell Step-up Substation will include the service to Hvolsvollur, two banks of the single phase main power transformers, and four switchyard bays. The fifth bay and the last bank of main power transformers will be added in Stage III.

Transmission Lines

All of the transmission lines will be 230 Kv on wood-pole construction. Single circuits will be provided from Burfell to Irafoss and from Irafoss to Geithals. A double circuit will be provided from Geithals to Straumsvik. Conductor will be 795 MCM-ACSR. The portion from Burfell to Irafoss is 60 kilometers long and will be routed to pass adjacent to the proposed Vordufell Pumped-Storage Project, as presented in Report No. 14 of Appendix A. The portion from Irafoss to Geithals will be 34 kilometers long. Each circuit from Geithals to Straumsvik will be 17 kilometers long.

Irafoss Intertie

An emergency intertie will be made to the 138 Kv bus at the Irafoss Switching Station (which provides service for the Sog system) from the 230 Kv transmission line arriving from Burfell and extending to Geithals. A single bay is required and it will be located adjacent to the existing Irafoss Substation. The bay will include a 70 MVA 230/138 Kv auto-transformer, a circuit breaker and disconnects. The disconnect between the auto-transformer and the 230 Kv line will be normally open inasmuch as this Intertie is provided for emergency purposes.

The Irafoss Intertie will be complete in Stage I. The estimates, however, contemplate that the Intertie will be removed in Stage IV and transferred to the Geithals Receiving Substation to represent another bay therein with the auto-transformer providing additional service to the Reykjavik load.

Geithals Receiving Substation

The Geithals Receiving Substation will consist of a 230 Kv portion and a 138 Kv portion. Both will be of the double bus arrangement. The 230 Kv station will consist of 7 bays, each containing circuit breakers and disconnects. Three bays will serve the incoming and outgoing 230 Kv transmission lines and 3 bays will serve corresponding bays in the 138 Kv Switching Station. The seventh will be for transfer.

Three 70 MVA 230/138 Kv auto-transformers will be provided for service to the Reykjavik area. Two of these will be provided in Stage I. The third will be transferred from Irafoss in Stage IV.

The 138 Kv portion of the Geithals Receiving Substation will contain 8 bays, each containing circuit breakers and disconnects. Three bays will serve the three 70 MVA auto-transformers, one for each. Four bays will serve the outgoing 138 Kv transmission lines; 2 to Ellidaar, 7 to Irafoss, and 1 to Korpulfsstadir. The eighth bay will be for transfer.

The Geithals Receiving Substation will contain a common operating building to house the control boards and communications equipment for both portions of that Receiving Substation.

In Stage I the 230 Kv portion of the Geithals Receiving Substation will include 5 bays, but the bay serving the reserve 70 MVA transformer will not include a power circuit breaker, which will be added in Stage III. Also in Stage III the sixth bay will be added to provide for transfer. In Stage IV the seventh bay will be added to connect with the auto-transformer moved from Irafoss. The three 230 Kv disconnects will also be moved to Geithals.

In the 138 Kv portion of the Substation 5 bays will be included in Stage I. Two bays with breakers and disconnects will be added in Stage III, one to connect with another 138 Kv transmission line to Ellidaar, and the second to provide for transfer. One bay will be added in Stage IV, to connect with the auto-transformer moved from Irafoss. The power circuit breaker and the 138 Kv disconnect will also be moved from Irafoss.

Straumsvik Receiving Substation

The Burfell Project will include a 2-bay Receiving Substation at Straumsvik contiguous with the Substation belonging to the smelter and using common buses therewith. A double bus arrangement is provided. Disconnects in each of the 2 bays will be the only equipment provided.

The Straumsvik Receiving Substation will be constructed in Stage I.

Chapter V

CONSTRUCTION

General

It was necessary to make assumptions with respect to the construction of the Burfell Project, as presented in this Definite Project Report, in order to provide a proper basis for estimating costs. These assumptions are logical, taking into account the designs, physical factors, location, labor supply, completion by Stages to meet the expected Southwest Iceland power demand, common practices which have been developed by experience within the construction industry for hydroelectric projects, and many other factors. Some of the more important assumptions which were made are presented below in general terms.

The Project will be accomplished by contract (s). In general, all Stages of construction will involve competition by qualified construction contractors, and by material and equipment suppliers and manufacturers from throughout the free world. However, some of the smaller items of construction in Stage I as well as the general construction items of the three subsequent Stages may be limited to Icelandic contractors, possibly in association with foreign ones.

General Construction

The general construction of Stage I will be done by one or more large foreign contractors highly experienced in hydroelectric construction. Two principal construction contracts are contemplated. The first contract will be for the general construction of the Thjorsa Diversion Features, Direct Power Features and Burfell Sending Substation. The second contract will be for the construction of most or all of the Transmission Features. Major items of permanent equipment will be furnished these contractors for erection. The general construction contract is planned for award in early 1966, followed by the Transmission Features construction contract at the end of 1966.

Other Stage I items of construction may be accomplished by force account or by smaller contractors, including Icelandic ones. These work items may include the Access Roads and Bridges, Operators' Village, Burfell Reservoir Features, and possibly some minor items which may not be included in the general construction contracts. Also some of the work under the general contracts may be subcontracted, either to qualified Icelandic or foreign firms. Local services will almost certainly be largely subcontracted.

Labor

Icelandic labor, both skilled and unskilled, will be used for the Stage I construction to the maximum extent available. The same applies to engineers, technicians, accountants, clerks, and supervisory personnel. The foreign contractors and the supervising engineers will provide key supervisory personnel and some special employees from abroad having skills not available in Iceland. It may still be necessary to import some labor in view of the overall labor demand resulting from the coincident construction of the Burfell Project, the smelter, its associated harbor, and the normal construction in Southwest Iceland, and also in view of Iceland's somewhat limited construction labor supply. The possible labor shortage during Stage I construction is expected to have eased, at least relatively, during the construction periods for the subsequent three Stages even though some smelter construction would be coincident.

A high percentage of the Burfell Project costs in all Stages will represent Icelandic payrolls, both on the actual work and in such support matters as transport, services to both domestic and foreign personnel, off-job equipment maintenance, etc. Nearly all of the labor costs associated with the general construction of the last three Stages can be expected to be Icelandic payrolls, especially if much of the work is accomplished by Icelandic contractors.

Plant, Material & Equipment

Nearly all of the plant, material and equipment in all Stages will need to be imported. Imported construction materials will include such items as fuels; steel products; timber and lumber; processed plastics, rubber, and non-ferrous metal items; etc. Cement is produced in probably adequate quantities in Iceland and may be used. The cost estimates, however, are based on imported cement pending determination of adequacy and suitability of Icelandic cement.

Modern heavy construction equipment and machinery will be used. In Stage I, a major portion may be purchased by the general contractor for the account and ownership of the Icelandic government entity. Some residual might be available for the subsequent three Stages of construction. The cost estimates of all three Stages are based on importation of all construction equipment and machinery requirements with the delivered cost written off on the Project; salvage values were not considered. Local contractors may have on hand a relatively small amount of used equipment serviceable for that part of the work.

All of the Project's permanent equipment was considered to be imported, shop fabricated to the maximum feasible extent. However, some of the smaller items, such as steel gates, might be fabricated locally using imported materials. This fabrication will not apply to highly specialized complex equipment.

Natural Construction Materials

The extensive field investigations and tests, presented in several of the earlier reports of Appendix A, developed the availability of suitable natural construction materials in adequate quantity within reasonable haul distance of the Project. These include coarse and fine concrete aggregates, impervious core material, filter and rock shell material, riprap, road metal, etc.

Construction Scheduling

On the basis of the designs, the requirements to meet load demands, and the appropriate above construction assumptions, a bar graph construction schedule was prepared and is shown on Exhibit 12. Details of the construction procedures assumed are discussed below. Actual procedures, including sequences used by the successful contractors may, of course, differ from the assumptions, but should not tend to increase costs or construction time. The schedule for Stage I shows that the key items of construction are the Direct Power Features, including installation of equipment, resulting in a construction period of slightly more than three years, not including the engineering preparation of contract drawings.

The general construction work for the last three Stages can be accomplished in two years each. The overlap of Stages III and IV suggests that these Stages might be combined for construction purposes. It will be necessary to place orders for the main generating equipment of each of these three Stages about nine months in advance of the beginning of general construction in order to assure delivery in adequate time for installation.

In order to complete Stage I in time for power and energy delivery to the smelter potline by mid-1969, it will be necessary to start the excavation for the Power Features water conductors not later than the early part of 1966. Further, the award of contracts for the purchase of turbines, governors, and generators must be accomplished by early 1966. Engineering designs are now proceeding on these contract award bases.

Construction Procedures

The construction procedures assumed are one of the important bases for establishing the unit costs basic to the Summary Estimates presented in Exhibit 13, and are considered logical therefor. The basic designs tend to control general procedures and sequences. Therefore, major departures from the following assumptions during actual construction are not considered probable.

The Powerhouse excavation is of critical importance and will represent the initial construction in order to permit the commencement of driving the lower legs of the Penstocks by the earliest feasible date. All of the work associated with the horizontal legs of the Penstocks including excavation, concrete and steel lining, and grouting must be accomplished utilizing the area of the Powerhouse excavation for access. The same is true for the excavation of the vertical legs of the Penstocks, but their concreting will be accomplished from above. These Penstock operations will require about two years and coincide in point of time with much of the concreting of the Powerhouse, requiring close coordination and efficient operations. The right Penstock and right three generating bays of the Powerhouse will lead the Powerhouse phase of the construction inasmuch as they will be the operational elements of Stage I.

The Tailrace excavation, for the most part, will be accomplished late in the construction program, when the draft tubes can be bulkheaded to exclude water from the Powerhouse. The retention of the material in place will provide a natural cofferdam for as long as is feasible.

vertical legs ofthe Penstocks, will be used for excavation of each of the Surge Tanks, except that the horizontal connecting conduit will be driven by the full face method. Thus, nearly all of the Surge Tank excavation will be hauled out through the upper portion of the Penstocks and the Power Tunnel.

The contractor, at his expense, will be permitted to open an adit or adits from downstream to assist with the construction of the above features but only without hazard or interferences to the construction of the Powerhouse and related operations in that area.

Placement of structural concrete in the Power Tunnel, and in the lining of the horizontal and vertical legs of the Penstocks, will be accomplished by pumpcrete methods behind either wood or steel forms, including the steel liners. The invert paving of the Power Tunnel will be accomplished by direct haul. Concreting of the Surge Tanks will be accomplished from above. Some support is expected at zones of weak rocks in all of the various underground excavations discussed above. Steel sets with timber and steel lagging will be installed at the time of excavation, then incorporated later within concrete lining. Rock bolting will be used liberally throughout and nearly all bolts within the underground excavations will be of the grouted type.

The excavation for the Approach Channel and the Samsstadaklif Sluiceway are not particularly critical in point of time. The suitable rock excavation therefrom will be available for the shells and riprap of a portion of the Bjarnalaekur Dike, and for project access and haul roads.

The shells of the Samsstadaklif Dike will be constructed by direct haul of suitable excavation from the Power Tunnel and Approach Canal, after excavation to suitable foundation levels. The downstream shell will be constructed conveniently to full height, followed by placement of the sloping core and filters. The upstream shell will be placed last. The core material will come from a morainal deposit located about 200 meters southwest. Filter material will be selected bank run material from deposits in the beds of either the Fossa or Thjorsa.

The lapilli overburden excavation for the Diversion and Bjarnalaekur Canals and portions of the Bjarnalaekur Dike foundations may, if the contractor so selects, be removed by controlled diversions of the Thjorsa to the Bjarnalaekur. Such a procedure could sluice the material to downstream rather economically. However, the cost estimates are based on removing this light weight material by conventional excavation procedures.

Suitable rock from the excavations for the Bjarnalaekur Canal, Diversion Inlet and Diversion Canal will be used for construction of the rock shells and riprap of the Bjarnalaekur Dike to the required section for Stage I shown on Exhibit 6. In Stage III the excavation of the enlarged left side of the Diversion Canal will provide shell material for completion to full section. Any additional rock required will be supplied from the Approach Canal excavation either by direct haul in Stage I or from the disposal piles in Stage III, as appropriate.

The widening of the Diversion Canal on the right side in Stage III will provide rock shell and riprap material for the Right Bank Dike to be constructed in that Stage.

Impervious core material for the Stage I construction of the Bjarnalaekur Dike will come from either the morainal deposit referred to above or loessic soil deposits located along the right bank of the Thjorsa about five kilometers upstream of the Diversion Inlet. The former source will be used for the Stage III construction. The latter source will be used for the core of the Right Bank Dike.

Filter materials for these two Dikes may come either from suitable deposits in the Fossa near the Powerhouse, in the Thjorsa downstream of its confluence with the Fossa, or deposits located about six kilometers upstream of the Diversion Inlet on the right bank of the Thjorsa. Processing is considered necessary.

The Left Bank Dike, to be constructed in Stage I, will have two somewhat different sections, as shown on Exhibit 6. Rock shell material for both will be quarried from the Hekla lava front near the left end of the Dike, and filter materials will be manufactured from this same source, or obtained from a river bar below Trollkonuhlaup. Impervious core material will come from a loessic soil deposit located about 5 kilometers upstream along the left bank of the Thjorsa. Sand core for the left section will be obtained by the stripping of thin surface deposits in the contiguous area.

Neither the construction of the Dikes nor the excavation of the Canals presents any critical time problem in either Schedules I or III. This construction will proceed only in the summer seasons of good weather.

The embankment section of all of the Dikes will be constructed by conventional rolled filled methods. Conventional construction equipment of medium to heavy size draglines, power shovels, bulldozers, etc., will be used for all embankment and open excavation. Rubber tired dumptors and medium-sized trucks will be used for hauling the muck from underground excavations, depending on tunnel size. Full tracked loaders will be used within the tunnels. All drilling equipment will be conventional.

An aggregate plant for processing concrete aggregate will be located on the south slopes of Samsstadaklif to process rock from a quarry near the top of that small mountain. Some of the muck from the Power Tunnel may prove suitable and thus provide a supplemental source after initial stockpiling. A dry batch plant serving the entire main Project area will be provided in the vicinity of the aggregate plant. Aggregate will be processed in Stage I and stockpiled to meet the requirements of the three subsequent Stages.

Mixing and transport of concrete for the structures will be by transit mixers, with minor amounts mixed by portable mixers. As mentioned above, placement will be mostly by pumpcrete for concrete located underground. For the surface structures and the Surge Tanks the concrete will be placed by bottom dump buckets handled by cranes. Concrete required for the Transmission Features, except the Burfell Sending Substation, will be purchased commercially, or mixed with portable mixers.

Construction of the concrete structures located above ground will be by conventional methods. Of these features only the Powerhouse requires year-around construction. Accordingly, winterizing will be provided by plastic sheets supported by wooden or metal frames.

Cofferdams will be required to handle the Thjorsa during construction of the Diversion Weir, Bjarnalaekur Canal Sluice Structure and Diversion Inlet in Stage I. A first stage fill cofferdam will enclose the latter two and the ultimately gated section of the Diversion Inlet, tied to the right bank of the Thjorsa upstream of the Inlet and downstream of the Sluice Structure. The remainder of the Diversion Weir will be surrounded by a second-stage fill cofferdam after removal of the first-stage one. The completion of the Diversion Weir in Stage III will require only a bulkhead on the upstream side of the gated section.

The early construction of the Bajarnalaekur Control Structure will permit diversion of the Bjarnalaekur while that portion of the Bjarnalaekur Dike is constructed.

The installation of the Powerhouse equipment will be included in the main general construction contract and will be accomplished conventionally. The Powerhouse will be enclosed fully as early in the construction program as is feasible. The main machine hall will be served by two overhead bridge cranes which will unload electrical and mechanical equipment onto the erection bay floor and later lift it into final position. The heaviest lift, which will be that of the generator rotor, is estimated at 140 metric tons, and will require the use of both cranes.

The construction of the Transmission Features will be by conventional methods and is not expected to involve any unusual construction problems. The same is true of the Access Roads and Bridges and the Operators' Village. It is expected that the main Access will be complete or nearly so by the time the main general construction contract is awarded, and that a substantial portion of the Operators' Village will be complete early in the construction program of Stage I.

The general area of the main Project is moderately open and level, providing adequate areas of flat ground for camps, yards, and work areas, Construction roads within the area present no unusual problems, and must be constructed early in the construction period. The Transmission Features, for the most part, are located in nearly level and open areas without serious access problems. The Transmission Features for Stage I will be constructed in the summers of 1967 and 1968, with equipment installation accomplished during the last season.

The construction of the Thorisvatn Initial Storage will be accomplished during the two summer seasons of 1972 and 1973. Except for the concrete outlet structure, a relatively minor item, the construction consists of open excavation, mostly unconsolidated. Heavy excavation equipment will be used. The opening of the canal into the lake will be accomplished after the control structure is completed early in the summer of 1973. An at-site construction camp and maintenance shop will be required. An access road of reasonable quality is required, but the exact alignment has not been established. It will represent an extension of the Access Road, constructed in 1966, to the Left Bank Dike.

Chapter VI

PROJECT COSTS

Capital Costs

Cost estimates for the Burfell Project presented in this Definite Project Report were prepared for each of the four Stages representing progressive construction to provide generation to meet expected power demands. Summary Cost Estimates only are presented in this Report as Exhibit 13. All costs, local as well as foreign, are expressed in United States Dollars. The rate of exchange used for converting Icelandic Kronur to U. S. Dollars was 43 Kronur to one Dollar.

The construction costs were prepared from detailed quantity surveys based on the Project drawings and on estimated unit prices for construction work. Lump sums were included for costs of permanent equipment and other items which could not be estimated conveniently by the unit cost procedure. The unit prices and lump sums were estimated on the basis of labor rates and the cost of material and equipment as of April, 1965, with some allowance for principal contract awards in early 1966.

The construction of each Stage of the Burfell Project was based on utilizing the services of foreign contractors. Some participation of local contractors, however, is expected, especially in the Stages involving installation of the last three generating units. Construction equipment and such material as steel, lumber, and fuel was considered to be imported. Also, cement was assumed in the cost estimates to be imported, but Icelandic cement may be used in the actual construction depending on availability and quality for the type of work involved. Labor, both skilled and unskilled, was assumed to be available locally.

The unit prices basic to the detailed cost estimates used to evolve the Summary Cost Estimates include contractor's plant, equipment, overhead, profit, performance bond, applicable taxes, and insurance. Customs duties and taxes on imported equipment and materials were not included.

The estimated costs for the main permanent electrical and mechanical equipment were based on recent quotations from well-known Western European manufacturers, and also their recent bids on generally comparable equipment. All costs are for the equipment fully installed. Installation will be by the general contractors, not by the manufacturers acting as construction contractors. No allowance was made for land values as a cost item.

Contingency allowances were added to the subtotals of the estimated direct construction costs as an indirect item. These allowances are intended to cover possible unforseen difficulties of construction, omissions from the estimates, some degree of price escalations, and some importation of foreign labor. The effects of any changes in rate of exchange are not included.

The contingency allowances were varied somewhat. Approximately fifteen percent was applied to the foreign exchange component of the civil works and Transmission Features, and about five percent to the purchase price of the permanent electrical and mechanical equipment. Approximately twenty percent was applied to the domestic currency component of the Project, which component is dominated by local labor costs. At the present time, local labor costs over the period of construction present some uncertainties.

Engineering costs associated with design and the engineering supervision of construction plus the owner overhead costs prior to and during the construction period of each Stage were estimated to be about ten percent of the subtotal of Direct Construction Costs plus the Contingencies. The State Electricity Authority of Iceland expended about $800,000 as "Preliminary Costs" on behalf of the Burfell Project prior to July, 1964 and these expenditures were incorporated in the Stage I estimate. The costs estimated for Stages II, III, and IV were on the assumption of a single construction program incorporating these Stages with Stage I. Accordingly, with these last three Stages, an allowance was made to each Stage for "Added Cost Due to Incremental Construction."

The Thorisvatn Initial Storage, to be constructed in Stage III, was estimated as though it were a separate project, therefore its estimate in the Summary of Exhibit 13 includes contingency and engineering and overhead costs.

The "Total Construction Cost" of Exhibit 13, for each of the four Stages, represents the addition to the "Direct Construction Cost" of the estimated costs for Contingencies, Engineering and Overhead, Added Cost Due to Incremental Construction, Preliminary Costs, and Thorisvatn Initial Storage, as appropriate.

The estimated Construction Costs by Stages divided as between domestic and foreign currency requirements are scheduled by years on both a commitment and disbursement basis on the following Table VI-I. Differences between commitments and disbursements are accounted for by an assumed ten percent withholdings on construction and equipment supply contracts which would be released after contract completion and satisfactory equipment performance.

The estimated fund requirements are summarized by Stages in U. S. dollars as follows:

Stage	Domestic Currency Requirements	Foreign Currency Requirements	Total
I	$ 11,500,000	$ 16,874,000	$ 28,374,000
II	386,000	1,232,000	1,618,000
III	2,308,000	3,547,000	5,855,000
IV	311,000	1,095,000	1,406,000
TOTALS	$ 14,505,000	$ 22,748,000	$ 37,253,000

No estimates were made for the costs of interest during construction or capitalized reserves and working capital for any of the Stages inasmuch as there are dependent on financing arrangements, which have not as yet been established.

The total disbursement requirements by years are estimated from Table VI-I to the nearest 0.1 million U. S. Dollars as follows:

Year:	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
Requirements:	1.0	1.2	3.5	10.5	9.4	2.8	0.7	0.8	2.9	3.0	1.4	0.1	37.3

The estimate for 1964 includes the $ 800,000 of "Preliminary Costs" in the Stage I Estimate plus an estimated additional $ 200,000 expended for the Project in the last six months of that year.

T A B L E VI-I

BURFELL HYDROELECTRIC PROJECT

CONSTRUCTION COSTS

COMMITMENTS AND DISBURSEMENTS

BY STAGES AND YEARS

DIVIDED BETWEEN DOMESTIC AND FOREIGN CURRENCY

IN MILLION U.S. DOLLARS.

A. STAGE I - THREE 35 MW UNITS

Year	COMMITMENTS			DISBURSEMENTS		
	Domestic currency	Foreign currency	Total	Domestic currency	Foreign currency	Total
1964	1.000	0.000	1.000	1.000	0.000	1.000
1965	0.600	0.600	1.200	0.600	0.600	1.200
1966	1.100	2.700	3.800	1.000	2.500	3.500
1967	4.100	7.500	11.600	3.700	6.800	10.500
1968	4.460	5.974	10.434	4.000	5.400	9.400
1969	0.240	0.100	0.340	1.200	1.574	2.774
Totals	11.500	16.784	28.374	11.500	16.874	28.374

B. STAGE II - ONE 35 MW UNIT

Year	Domestic currency	Foreign currency	Total	Domestic currency	Foreign currency	Total
1970	0.000	0.800	0.800	0.000	0.700	0.700
1971	0.386	0.432	0.818	0.360	0.400	0.760
1972	0.000	0.000	0.000	0.026	0.132	0.158
Totals	0.386	1.232	1.618	0.386	1.232	1.618

C. STAGE III - ONE 35 MW UNIT

Year	Domestic currency	Foreign currency	Total	Domestic currency	Foreign currency	Total
1972	1.308	1.700	3.008	1.200	1.550	2.750
1973	1.000	1.847	2.847	0.900	1.700	2.600
1974	0.000	0.000	0.000	0.208	0.297	0.505
Totals	2.308	3.547	5.855	2.308	3.547	5.855

D. STAGE IV - ONE 35 MW UNIT

Year	Domestic currency	Foreign currency	Total	Domestic currency	Foreign currency	Total
1973	0.000	0.500	0.500	0.000	0.450	0.450
1974	0.311	0.595	0.906	0.290	0.550	0.840
1975	0.000	0.000	0.000	0.021	0.095	0.116
Totals	0.311	1.095	1.406	0.311	1.095	1.406
GRAND TOTALS	14.505	22.748	37.253	14.505	22.748	37.253

No division is made in the above tabulation as between domestic and foreign currency requirements.

Annual Costs

The annual charges against a power system may include: interest on invested capital, depreciation of the installation or amortization of investment, reserves, annual value of water rights, insurance, taxes, profit, operation and maintenance expenses, administration and general expenses, and others.

The estimated annual operation and maintenance (O&M) expense in U. S. Dollars, based on present cost levels, as each Stage of the Burfell Project is completed is as follows:

Stage	Annual O&M Expense
I	$ 315,000
II	350,000
III	385,000
IV	420,000

The above costs may increase in future years dependent on the effect of any inflation.

Other annual costs of the Burfell Project will depend on financing terms and administrative policies and are considered beyond the scope of this Report.

The fundamental concept of the relative economy of the Burfell Project is considered as having been well established by the earlier Reports summarized in Appendix A.

Chapter VII

HYDROELECTRIC GENERATION

General

The Burfell Hydroelectric Project, as presented in this Definite Project Report, is designed basically as a run-of-river development to produce power and energy. This production will supplement that of the existing Southwest Iceland Power Supply System to serve the normal loads of that part of the country plus the progressive addition of an aluminium smelter load. The Burfell Project's power and energy production will be dependent on the water supply available in the Thjorsa at the point of diversion and on the head developed. Regulated storage upstream is not contemplated except for a small amount at the natural lake, Thorisvatn, and that storage is intended primarily for assistance in sluicing ice. The natural flow, therefore, represents the water supply available for hydroelectric generation. This supply is influenced by hydrology, climatology, topography and geology.

Water Supply

The undeveloped and uninhabited drainage basin of the Thjorsa upstream from the Burfell Project Diversion Weir has an area of about 6,350 square kilometers. The river originates with the Hofsjokull and Vatnajokull Glaciers which contribute to the streamflow by melting during the summer months. The topography of the basin is relatively rough as a result of the interaction of volcanic activity, glaciation, gravity forces, and stream erosion. The maximum elevation is about 2,000 meters.

Geologically, all of the rocks and surficial materials are of volcanic origin. Much of the basin area consists of relatively pervious formations which act as substantial groundwater reservoirs. Natural lakes formed by glaciation and by volcanic activity are numerous--the largest being Thorisvatn with a surface area of 70 square kilometers. These groundwater and lake reservoirs provide a substantial degree of regulation to the Thjorsa streamflows.

The climate in the Thjorsa Basin is rainy with cool summers of almost constant daylight and warmer winters than are normally associated with a location less than 300 kilometers south of the Arctic Circle. Haell, south of Burfell, has a recorded mean annual temperature of 3.7°C, and mean monthly temperatures of minus 1.8°C. in January and 11.4°C. in July. The weather is dominated throughout the Thjorsa Basin by air masses of maritime origin, mostly cyclonic systems which tend to follow the Gulf Stream and bring great volumes of humid, relatively warm air to Iceland, which is precipitated in frequent storms.

The precipitation in the Thjorsa Basin varies somewhat throughout the year, as well as with elevation. Precipitation is heaviest from September through March, although substantial in other months. The mean annual precipitation in the Thjorsa Basin is estimated to vary from 800 millimeters at the Project to 3600 millimeters at the glaciers, with the average being about 1700 millimeters, but there is no established meteorological station in the Basin.

Snow accumulates to great depths at the higher elevations during winter, but most of the precipitation below about 500 meters elevation is rainfall. Snow depths at the Project site rarely reach one-half a meter.

High pressure systems containing cold, dry air move in from Greenland usually several times each winter for periods averaging about five days each. Accompanying temperatures, however, rarely fall below minus 15°C at Burfell. Phenomena associated with these cold spells reduce the streamflow substantially and result in all extreme low flows of record. These cold spells result also in sludge ice conditions on the Thjursa requiring sluicing water at the Project's Diversion Features. Thus the combination of low flows and ice conditions during these cold periods are the most critical periods from the standpoint of energy generation at Burfell.

Streamflows in the Thjorsa at Burfell have been estimated from records of various gaging stations on the river and its tributaries, but primarily from the record at Urridafoss where the drainage area is 7200 square kilometers, or 13 percent more than at Burfell. The Urridafoss record began in September, 1947, while the other records are none earlier than in 1958.

The average annual streamflow at Burfell for the 15 water years from 1948 to 1962 was estimated at 338 cubic meters per second (cms). The maximum and minimum daily flows were estimated to be 1980 and 72 cms, respectively. The most critical period of extended low flow, that from mid-November 1950 to mid-April 1951, had an estimated average flow of 184 cms.

The frequency of daily flows for the 15-year period was estimated as follows:

Percent of Time Equaled or Exceeded	Daily Discharge - cms
100	72
98	140
95	159
90	178
75	221
50	309 (median flow)

Storage required to firm the flows of the critical winter period of 1950-51, discounting any consideration of flows utilized for ice sluicing, were established as follows:

Average Flow to be Maintained - cms	Storage Required Million Cubic Meters
145	6
174	54
203	337
232	747
290	1740

Head

The Burfell Project will operate under a nearly constant gross head of 118.5 meters, from El. 244.5 on the Thjorsa to El. 126.0 on the Fossa. This gross head will be about 1.5 meters less through Stage II and until the Diversion Weir is completed in Stage III. Minor changes in the gross head may be caused by floods or by ice jams downstream, but these changes will have little effect on the energy production or the power capability of the Project. The gross head will be increased by the amount of any degradation occurring in the Fossa after the plant is placed in operation, but this possible increment has not been considered in power and energy production estimates.

The net head on the turbines will depend on the hydraulic losses in the water conductors and variations in headwater and tailwater. Total hydraulic losses are estimated at about 1.7, 2.4 and 3.4 meters for station flows of 100, 150, and 200 cms, respectively, but these values will be subject to some slight variation depending on how the station flow is distributed between units. The headwater will remain relatively constant, while the tailwater will vary about one meter between 100 cms and full 6-unit station flow capacity, absent ice and flood effects.

Pondage

Some pondage will be available in the Bjarnalaekur Pond, which will have a surface area of about 1.3 square kilometers at the normal control level of 244.5. The upper one meter of drawdown will provide slightly more than one million cubic meters, adequate for a flow increase of 50 cms for a period of six hours. This is equivalent to about 50 continuous MW. It is considered feasible to withdraw 5.8 meters of pondage between elevations 244.5 and 238.7. The design of the Approach Canal will permit a flow to the Powerhouse of 100 cms at this minimum level. The pondage available is 5,000,000 cubic meters which would provide about 1.35 Gwh in the event of complete stoppage of diversion from the Thjorsa, equal to an average of 53 MW over 24 hours.

Power Installation

For purposes of this Definite Project Report a six-unit plant was selected with a normally rated unit size of 35 MW. This selection was based on studies presented in the earlier Reports of Appendix A, notably Report No. 10. Installation of generating units will be three in Stage I, followed by one each in Stages II, III, and IV. This installation schedule is designed to meet the expected load growth of Southwest Iceland, including the various increments of the proposed aluminium smelter and of the fertilizer plant. Any deficiencies to load in generation from the Burfell Project will be offset to the maximum feasible extent by the production of Reserve Stations, discussed below, and possibly to some extent by storage from the Thorisvatn Initial Storage.

Peaking Capability

The peaking power in MW, which the Burfell Project, as proposed in this Report, can deliver to the Geithals Receiving Substation has been estimated as follows:

	Stages			
	I	II	III	IV
Peaking Capability at Site	115	154	192	232
Transmission Losses	4	6	9	12
Delivered Peaking Capability	111	148	183	220

These capabilities may be reduced slightly during periods of floods in the Fossa, and, to a lesser degree, by floods on the Thjorsa, and when tailwater may be raised by downstream ice jams. The low flowc that occur occasionally on the Thjorsa will not affect this inherent capability because of the regulation possible in the Bjarnalaekur Pond.

Energy

The primary energy of the Burfell Project has been considered as that produced by a rated station flow of 112, 150, 188, and 224 cms for the installations of Stage I, II, III, and IV, respectively, to the extent these flows are available according to the flow estimates presented above. These flows were estimated to be available 99.8, 96.5, 86.2, and 75 percent of the time, respectively. No allowance was made for any firming water which might be available from Thorisvatn to the installations of Stages III and IV. On the other hand, no deduction was made for water which may be required from the firm flows for ice sluicing, especially in Stages I and II when Thorisvatn water will not be available for this purpose. These additions and subtractions are expected to be minor insofar as they may affect primary energy generation.

The overall efficiency (not including hydraulic losses in the water conductors which were reflected in the net head, but including transmission losses and station service) was estimated at 83 percent. Water utilization of the firm flows should be nearly 100 percent, but for purposes of conservatism a utilization factor of 98 percent was assumed in the energy estimates. On these assumptions, the average annual primary energy delivered to the Geithals Receiving Substation is estimated as follows:

Stage	Annual Primary Energy - Gwh
I	900
II	1190
III	1480
IV	1720

Some secondary energy will be available for extensive periods when available flows exceed that required to produce primary energy up to the turbine capacity at full gate, but has not been estimated.

Reserves

The relation of loads to resources for the assumptions of this Definite Project Report is shown on Exhibit 11. Both are referred to the busbars of the generating plants. The Exhibit presents only power values; energy values are considered somewhat less critical based on earlier analyses, as presented in Report No. 10 of Appendix A. The load demands of Exhibit 11 are based on the estimated normal load growth of Southwest Iceland, as presented in Report No. 13 of Appendix A, plus the addition of aluminium smelter primary power loads of 60 MW in mid-1969, 30 MW in mid-1972, and 30 MW in mid-1975. The load curve represents yearly peak loads assumed to occur in December of each year. The resources are based on the generator name plate ratings. Only Burfell and the 91 MW of rated capacity of the existing Sog and Andakill hydroelectric projects are considered as Resources.

Other generating stations, as of the end of 1967, associated with the Southwest Iceland System are considered as being in Reserve status and include the following:

Ellidaar Hydro	2.5 MW
Ellidaar Thermal	19.0
Westmann Islands Thermal	4.0
NATO Base Thermal	7.5
Total	33.0 MW

The estimated loads and resources relationship of Exhibit 11 show resources deficiencies at the ends of 1972 and 1973. If these deficiencies in peaking should occur, they may be offset by partial use of the above reserve capacity or that of other sources. Both Burfell and the Sog Plants will have some over-capacity resulting from full-gate turbine operation which might total 10 to 20 MW. Reserve capacity in gas-turbine installation(s) is expected to be in service by the above years. Pumped-storage capacity at Vordufell, discussed in Report No. 14 of Appendix A, is a possibility. Such additional new capacity is beyond the scope of the current Report.

It is recognized that reserve capacity is also required to provide a high degree of emergency service to the aluminium smelter during outages which may occur because of transmission line or ice problems, or from other reasons. Specific reserves therefor are also beyond the scope of this Report.

It is understood that the aluminium smelter may have a peak demand as high as 70 MW per potline. It is expected that adequate surplus capacity will be available from the Sothwest Iceland System to meet the difference between the firm and peak demands of the smelter for a high percentage of the time, but it has been assumed that the normal loads of Southwest Iceland would have priority on the surplus capacity.

Chapter VIII

ICE PROBLEMS

General

Ice represents the most serious problem associated with the operation of the Burfell Project. The Thjorsa, in the vicinity of the Project, carries extraordinary quantities of ice during cold periods. It is important to prevent, insofar as feasible, Thjorsa ice from interfering with power operations. Comparable relative quantities of ice carried by the Thjorsa are probably very rare in rivers in any other country in the world. Problems associated with the design of the Thjorsa Diversion Features include problems associated with the magnitude of moving ice masses and also those associated with the change of physical qualities at different stages of ice production, transportation, and accumulation.

Field investigations and research on the ice problem have been conducted for the past several years in the vicinity of the Burfell Project by engineers and scientists of the Government of Iceland. During the past year special assistance has been provided by a team of experts supplied under a grant by the United Nations Special Fund. Preliminary results have provided information for project design and form one of the bases for some of the comments which follow.

The ice in the Thjorsa which presents the major problem is represented by, or related to, sludge ice. Much of the Thjorsa in the vicinity of the

Project flows at velocities too high to permit the formation of sheet ice, except locally. Much of the water surface, therefore, is exposed to the cold and wind, and this, in combination with the turbulent water of the river which is generally shallow, produces favorable conditions for the creation of sludge ice. The ice crystals of the sludge ice form around nuclei consisting of snow crystals falling or blowing into the river and also silt particles representing sediment in the water or material blown into the river. These ice crystals have a tendency to form clusters. These clusters are believed to have a unit weight of between 0.3 and 0.4 kg/l. In general it is believed that the clusters of sludge ice will all or nearly all be floating near the surface whenever the water velocity is less than about one meter per second. With higher velocities such as occur in sections of rapids, some of the ice crystals and sludge ice clusters will be carried in the full profile of the river section, possibly in some proportion with depth to average velocity. In waterfalls all of the sludge ice and ice crystals are thoroughly mixed with all of the water.

Under certain conditions, not as yet fully understood, ice similar in composition to the sludge ice will gather on the stones on the bottom of the river. This "anchor" ice may be in part the result of radiation effects, particularly during the very long winter nights at the latitude of the Thjorsa, and in part represent "captured" sludge ice carried down by the turbulence from the surface. In some places in the Thjorsa channel the bottom ice will grow to reach near the surface, then gather with floating cluster ice to form small ice islands extending above the water surface. The depth and velocity relationships in the river which preclude the formation of such ice islands is not now known.

There are places in the Thjorsa where the floating sludge ice, possibly in some combination with the bottom ice, forms ice jams extending entirely across the river. They have been referred to as "ice carpet bridges." These tend to form in river sections which are relatively narrow and deep, such as not far downstream from a waterfall or a rapid. They may also form in island areas of the riverbed where the depth may be relatively shallow. To some extent the creation of the ice islands referred to above, in combination with other physical characteristics, may contribute to the formation of these ice bridges. The water stream will pass under these floating ice bridges and in the process carry floating ice farther to downstream.

The sludge ice as it gathers in the ice dam tends to become much more compact and appears to have a density of about 0.6 to 0.7 kg/l in the uppermost layer, with the density increasing downwards to nearly 0.9 kg/l in the lowest layer. This compressed sludge ice represents a substance very different from the floating sludge ice of loose structure. The change in quality is due primarily to regelation effects. However, the production of ice dams includes also the combined effect of supercooling, crystal growth, sludge ice drift and dynamic compression. The resulting ice dam has a reasonable degree of stability and in some places it will raise the river level considerably and store for a short time very large volumes of water. This water storage results in temporarily decreased flows downstream. The raised water levels sometime result in local sheet ice production, particularly adjacent to the shores.

These ice dams are ultimately broken up by water pressure, either by that of the stored water or that by floods which result from rainfall during subsequent warmer periods or from waters released from an upstream ice dam. Frequently the breaking of an upstream ice dam will result in breaking up ice dams farther downstream, resulting in what is referred to as a "step burst." These floods carry the ice masses downstream, and they may consist of a mixture of many types of ice including loosened bottom ice, broken-off blocks of sheet ice, normally floating sludge ice of loose structure, and the compressed sludge ice which makes up the major portion of each dam. Some of the ice blocks floating with the flood may be relatively large. Usually some of the ice in the dams remains as remnants along the shore to be either melted or carried away by a subsequent flood. In a few areas, notably below major waterfalls, the ice bridges may reach enormous proportions and even retain additional ice acquired from step bursts upstream. During unusually severe winters such as the past one, these major ice bridges may be present throughout most of the winter. The one below Thjofafoss, which accumulates nearly every winter opposite the mouth of the Fossa, may have some tendency to increase Burfell Project tailwater elevations slightly. On the other hand, the diversion of the river into the Fossa may change the flow characteristics in the Thjorsa downstream from the mouth of the Fossa sufficiently to prevent, most or all of the time, the formation of an ice bridge which would effect tailwater. The locations where ice dams form in the vicinity of the Burfell Project and which may affect that Project, are fairly well known. Besides the area below Thjofafoss, other areas include the island, Klofaey; not far downstream from Tangafoss; and braided areas on the Thjorsa downstream from Tangafoss and on the Tungnaa upstream from Tangafoss. No ice dams have ever been known to occur at the selected site of the Thjorsa Diversion structures of the Burfell Project.

An important consideration with respect to the development of the Burfell Project is to reduce, insofar as is feasible, the effects of ice on power generation. This involves the passing of the ice to downstream of the Diversion Inlet such that ice will not accumulate and make a blockage of the diversion of water to the powerhouse. It may also involve the reduction in the amount of ice reaching the location of the Diversion Inlet. The former is involved directly with the engineering designs of the Diversion Features. The second may include the reduction of the water surface area upstream of the dam, preventing blowing snow from entering the river, and retention of ice in artificial upstream ice dams.

The studies to date have advanced the designs of the Thjorsa Diversion Features in recognition of the ice passing problems to the extent where these designs are now in the process of checking in a hydraulic model study being conducted at The River and Harbour Research Laboratory of the Technical University of Norway at Trondheim. These model studies, which have recently begun, may develop the need for some changes in the details of the designs in order to provide optimum structures for passing ice. It is not now believed that the basic concepts of the designs will need to be changed. Further, it is not now believed that any modifications in the details of the designs will have any important effect on the cost estimates for the Project.

It is believed that adequate surplus water will be available most of the time with 4 units installed for sluicing ice to downstream of the Diversion Weir and Bjarnalaekur Canal Sluice Structure. However, some reduction in flows diverted for power may be required under the most severe ice conditions. Deficiencies in energy to load would need to be provided by the production of reserve stations. With the addition of the fifth and sixth generating units at Burfell, supplemental water intended primarily to assist with ice sluicing will be provided from the Thorisvatn Initial Storage, as discussed more fully in Chapter IX.

It is considered feasible to reduce the amount of ice carried by the river to the vicinity of the Diversion Features. One method, which is included in the Project costs, involves the reduction of the open water surface area upstream of the dam which is exposed to sludge ice formation. This will involve confining the Thjorsa and Tungnaa in the braided upstream reaches discussed above to fewer or to only a single channel. Groins would be used for this confinement and are included in the cost estimate for Stage I.

Some of the blowing snow will be retained behind snow fences on the lee side and prevented from entering the Thjorsa where it would contribute to sludge ice production. Latticed woven wire fencing, commonly used in highway maintenance, will be used. Snow fences on both sides of the river upstream from the Diversion Features to near the mouth of the Tungnaa are included in the cost estimate of Stage I.

Consideration will be given to artificially creating ice jams at reasonably safe upstream points to at least temporarily retain some of the ice now reaching the Project area. Such a procedure has reportedly

The solution to the ice passing problems at Burfell can be expected to involve, at times, some sacrifice of water which could be used for firm energy production. During such periods it may be necessary to curtail loads or to utilize more expensive energy from reserve capacity. Such operational procedures are common utility practice where the utility is dependent primarily on hydro power and energy. Curtailing flow to power generation in order to alleviate ice problems can therefore be compared to low flow periods in any hydro system. From the standpoint of flow available for firm power, Burfell compares favorably with most hydro projects anywhere, even considering the ice control problem. While ice conditions may occur, generally for relatively short periods insofar as severity is concerned, over nearly one-half of each year at Burfell, the net effect on firm energy production is expected to be very small percentagewise. Further, a complete shutdown caused by ice, with vigilant and efficient operation of the facilities to be provided for ice control, appears to be highly unlikely.

A common ice problem at many hydro plants during periods of frost is the freezing of control gates to the extent that their operation is inhibited or prevented. This problem will be solved at the Burfell Project by the provision of heating elements and air bubbler systems wherever appropriate.

Chapter IX

THORISVATN INITIAL STORAGE

General

The large natural lake, Thorisvatn, represents the most attractive possibility for seasonal storage development in the Thjorsa Basin. Adequate natural storage is available to permit seasonal or holdover storage of its own controllable inflow and the flow of the Kaldakvisl by diversion of that Thjorsa tributary into the lake. Potential development of Thorisvatn as a storage reservoir is discussed in earlier reports, notably Reports Nos. 1 and 5 of Appendix A.

Thorisvatn has a surface area of about 70 square kilometers and a nearly constant level of 571. Storage in the upper 10 meters averages about 63.5 million cubic meters per meter. The lake is fed almost entirely by springs issuing from the porous lava to the east, and thus there may be substantial underground storage in addition to the open-water storage.

The surface outlet of Thorisvatn is northward via the Thorisos to the Kaldakvisl as shown by the Key Plan of Exhibit 10. The Key Plan also shows the location of the Burfell Project with respect to Thorisvatn. There is some leakage from the lake westward, estimated to be between 7 and 10 cms. The average flow of the Thorisos is about 14 cms and is rather constant, seldom dropping below 10 cms. These Thorisos flow values are based on only 4 years of record, and there is some indication that the record may be conservative on the low side. Further, the location of the gage may not represent the actual outflow of the lake in that direction, but any discrepancy is considered to be relatively small. The important consideration with regard to flows through Thorisvatn is the net inflow useable for refilling the reservoir after drawdown, especially after utilization of storage during the preceding winter. Unregulated outflows from the lake reach Burfell in any event. Withdrawal of storage and resulting lower lake levels will reduce these outflows and thus reduce the natural flows reaching Burfell approximately an equal amount, which must be offset by an equal rate of storage withdrawal in excess of the amount required for ice sluicing and firming flows.

The possible need for water from storage to assist in sluicing ice downstream past the Burfell Diversion Inlet and for firming Thjorsa flows for power in the last two Stages is discussed earlier in the main body of this Report. These requirements are relatively small compared to the total potential of Thorisvatn as a major storage reservoir. An Initial Storage project at Thorisvatn to provide these flow requirements is included in Stage III of the Burfell Project. This relatively small development can be accomplished without conflicting with the fuller development of Thorisvatn required for the future development of the water resources of the Thjorsa Basin, including expansion of Burfell beyond the Project presented in this Report.

The Thorisvatn Initial Storage cannot be justified economically on the sole consideration of firming flows. Utilization of the storage for assistance in ice sluicing is now considered the dominant function, especially since the ice conditions coincide generally with low natural flows. Further, the cold spells associated with the ice conditions tend to increase power and energy demands making it important to assure that Burfell meets its primary level of load carrying ability insofar as is feasible or justifiable.

Storage Requirements

Analyses of the estimated historic flows at Burfell revealed that flows less than the 6-unit rated turbine flow capacity of 224 cms occur every winter within the period from November through April. The low flow periods are of two types: (1) short periods resulting from severe frost (Type I), and (2) longer periods resulting from general drought conditions, usually associated with extended periods of cold (Type II). The Type I periods are relatively short, extending up to about three weeks, with an average of about one week. In some winters there were as many as eight such periods, with the average being four. Intervening higher flow periods will usually permit substantial replenishment of storage withdrawn from Thorisvatn. In general, Type I periods appear to present no problem with respect to either storage quantity available or withdrawal rate from Thorisvatn. Moreover, the operating experience at Burfell through the years preceding Stage III construction should give some definite information relative to the requirements for ice-sluicing water during these brief cold spells of floating ice and reduced natural flow.

The records at Urridafoss, which are considered somewhat questionable for low flow periods, show two major Type II periods, one in 1951 and the other in 1957. The former was by far the most severe, extending from

February 13 to May 1. Further, the stream flow decreased more or less gradually and did not begin to increase until about the last 10 days of the period. Based on the Urridafoss record, the cumulative flow deficiency below the plant rated flow of 224 cms may require on the order of 500 million cubic meters of storage at Thorisvatn, absent any consideration of requirements for ice sluicing. This amount of surface storage would be available in the top 7 meters of Thorisvatn, but the development costs thereof might be prohibitive for Burfell alone. Primary energy deficiencies at Burfell resulting from a long and severe low flow period would, to the extent not provided by the actual initial Storage constructed at Thorisvatn and if actually needed for the load, have to be supplied by other stations in the Southwest Iceland Power Supply System, including Reserve stations.

The establishment of the quantity of Initial Storage at Thorisvatn based on provision of firming flows for power alone does not appear to be a feasible approach. The dominant consideration with respect to both useable storage and minimum discharge rate must be based on requirements for ice-sluicing water. Actual operation of the storage for this dominant purpose will very likely provide some water at times for firming power flows.

Neither the rate nor the seasonal quantity of water required for substantial ice control at Burfell is determinable at this time. In general, the greatest ice problems can be expected to occur coincidentally with lowest natural flows since both relate normally to extreme frost periods. Requirements for water to control ice might also occur before, after or between some periods of low flow less than the station's primary flow capacity. Further, it is possible that ice-control water may be required at some more or less constant minimum rate throughout a major portion of nearly all winter seasons, but augmented further for relatively brief periods during the most severe periods within each winter, including those similar to the critical low flow year (1951). Thus it may be that ice control water could represent a substantial volume of storage, even exceeding the amount needed for firming energy during the entire year. Further, the required rate of release may be equally as great.

Provision of storage by a few meters of controlled drawdown at Thorisvatn, without any specific provisions for controlling present natural outflows is feasible and will provide substantial benefits with respect to both ice control and firming energy at the Burfell Project. Specific design criteria do not exist at this time for any high degree of exactness in planning the development.

The designs of the outlet works presented, and the costs thereof, represent an Initial Storage development at Thorisvatn permitting utilization of the amount of storage which it is believed can be refilled almost every year.

The Initial Storage development provides for utilization of 4 meters of storage from Thorisvatn down to El. 567, with a release rate at that elevation of about 75 cms. The reduction in natural outflow at this lake level may be on the order of 5 to 15 cms, depending on inflow. Accordingly, the rate of storage release representing actual increases to unregulated flow at Burfell would be between 60 and 70 cms. An additional nearly 4 meters of storage could be released, but at a progressively lesser net rate. The storage volume in the top 4 meters of the lake is about 275 million cubic meters of open water storage. The volume in the next lower 4 meters would be nearly the same. Underground storage, which may be substantial, would be in addition thereto.

Project Description

The location of the outlet works for the Thorisvatn Initial Storage will be through a low saddle near the southwest end of the lake, as shown by the key plan of Exhibit 10. This Exhibit also shows the plan, profile, and a typical section of the outlet canal, the plan and a section through the control structure, area-volume relationships of the reservoir, and outlet capacity of the outlet works in relation to the Thorisvatn water surface level.

The outlet works will consist of an open canal about 3 kilometers long. Control will be provided by a concrete structure positioned in the downstream portion of the canal and equipped with a gate. The grade of the canal will be dropped a few meters ahead of the control structure, then continue somewhat more steeply through the discharge channel to connect with natural water courses extending to the Tungnaa upstream of Tungnaarkrokur. Releases will cause considerable erosion between the location of the control structure and the Tungnaa, especially during the early months of operation. Ultimately a reasonably stable channel should develop. The eroded material will add somewhat to the bedload and suspended load in the river downstream, but no serious detrimental effects are expected.

The canal was designed to be constructed at minimum cost. The location was based on extensive topographic and hydrographic surveys, core borings, and Borro soundings. The alignment was selected to follow, without excessive curvature, both the lowest topography and the lowest bed rock profile. The total length of the canal will be about 3200 meters, of which about 200 meters will be in Thorisvatn and about 700 meters will be downstream of the control structure. The approach canal will be excavated on a uniform grade of 0.0013 from the entrance at El. 563 to El. 560 immediately upstream of the control structure. The canal will have a bottom width of 6 meters, side slopes of 2 horizontal to 1 vertical in overburden, and 1/2 horizontal to 1 vertical in rock. The discharge canal beyond the control structure will be of a design similar to the approach canal, but will have a slightly steeper grade of 0.002.

The profile of Exhibit 10 shows that most of the canal will be constructed in easily removable overburden. About 80 percent of the required excavation is expected to be in this overburden. The rock is not expected to be difficult to blast and excavate.

The detailed topography in the area of a presently undrained depression downstream of the canal at about El. 510 indicated that there is no immediate danger of flow diversion to the Kaldakvisl instead of to the Tungnaa. The deposit of eroded materials by the discharge waters in this depression may alter this situation unfavorably. Accordingly, a portion of the discharge channel excavation will be spoiled to build up dikes in the low saddles on the right side of the depression and assure diversion to the Tungnaa only.

The control structure will be a mass concrete dam crossing the canal about 2300 meters downstream of the lake. It will be provided with an undersluice for release of water as required. The structure will be approximately 15 meters high. A concrete-lined stilling basin will be provided immediately downstream of the gravity section to protect the foundations against erosion. The undersluice will be provided with a 3.5 meter square wheeled service gate operated by a hydraulic cylinder. An electric motor-driven hydraulic pump utilizing a storage battery power supply will operate the cylinder. A small gasoline engine-driven battery charger will be operated by periodic visits of personnel from Burfell at about monthly intervals. All normal operations of the gate will be by remote control from the Burfell Powerhouse.

While not indicated on the Exhibit, an emergency wheeled gate will be positioned in slots at the upstream side of the outlet structure and latched for immediate release by remote control from the Powerhouse. It may also be used for maintenance of the main service gate. Normal operation will be by a hand-operated hoist or, alternatively, by motor crane.

The hydraulic cylinder and operating equipment will be housed within a blockout below the deck level. This space and the gate guides will be heated by an oil-fired burner with adequate fuel storage to last the entire winter season.

All of the required construction is relatively simple and will be constructed in Stage III during the summer seasons of 1972 and 1973. The radio controls for operation are somewhat complex but not unusual for remote control operations of this type.

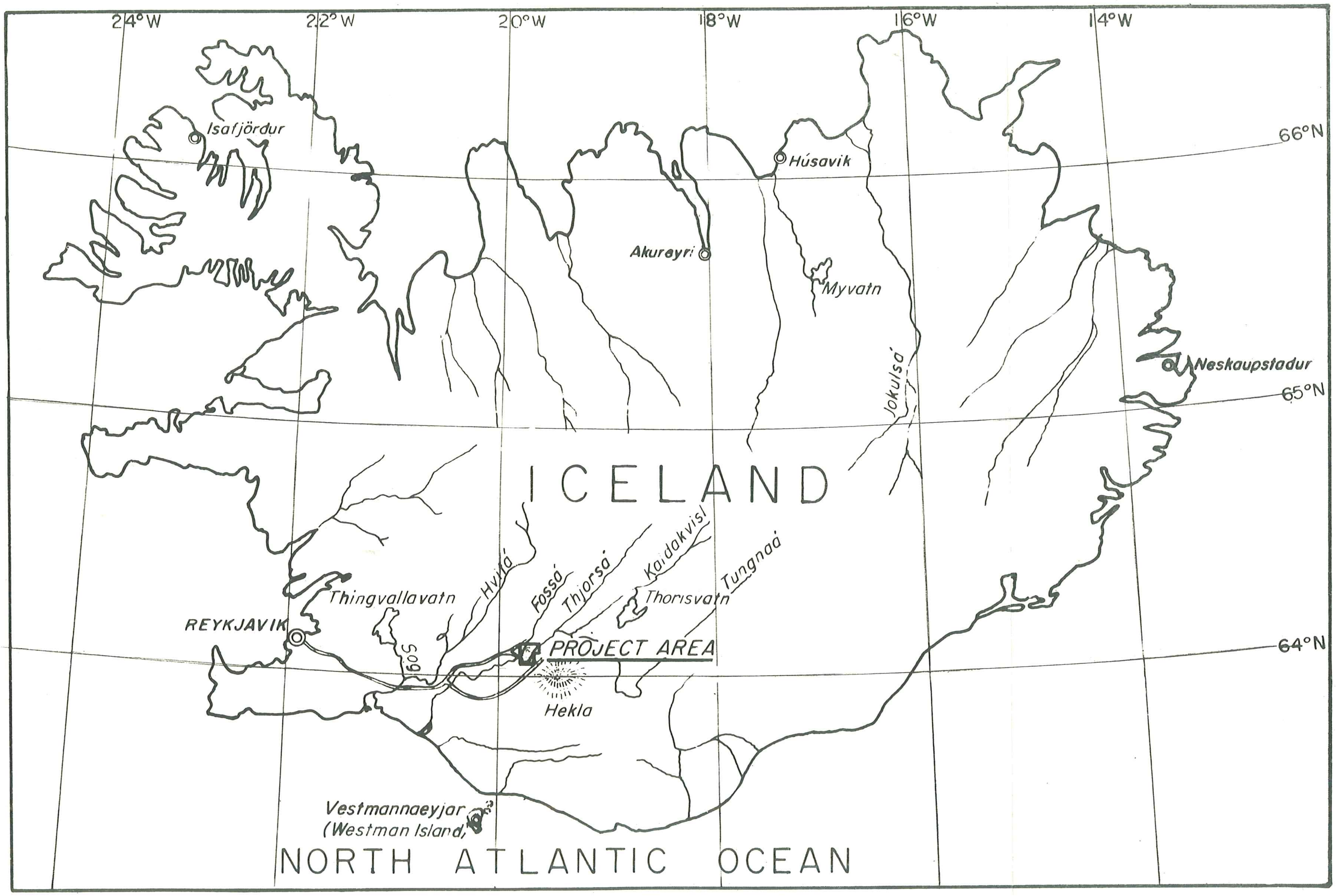
The total construction cost of the Thorisvatn Initial Storage was estimated to be two million U. S. Dollars. This amount includes contingencies, engineering and overhead costs, and some allowance in consideration of construction so far in the future essentially as a separate project from the other Burfell construction.

THE EXHIBITS

1. Key Plan
2. Transmission Line Route
3. Burfell Project Plan (Aerial Photograph)
4. Diversion Structures, General Plan
5. Diversion Structures, Weir and Inlet
6. Diversion Structures, Dikes and Canals, Profiles and Sections
7. Power Features General Plan and Profile
8. Powerhouse Sections
9. One-Line Diagram
10. Thorisvatn Outlet Works
11. Estimated Loads and Resources
12. Construction Schedule
13. Cost Estimate:

Stage I	Sheet 1 of 4
Stage II	Sheet 2 of 4
Stage III	Sheet 3 of 4
Stage IV	Sheet 4 of 4

EXHIBIT 1



Scale 0 — 100 Kilometers

LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT

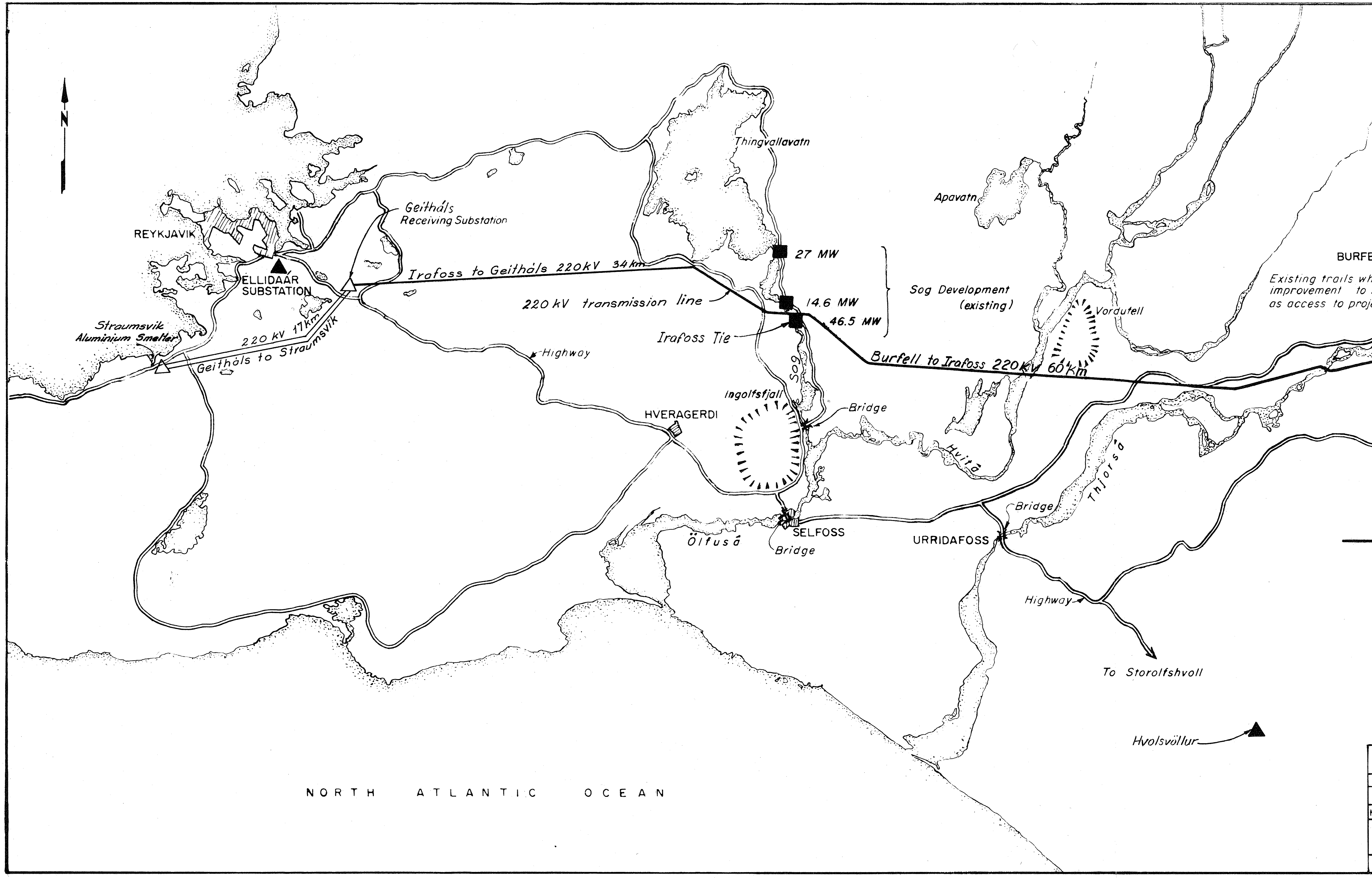
KEY PLAN

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED C. K. Willey

CHICAGO, ILLINOIS	DATE	DWG. NO. 290 SKC 16

EXHIBIT 2



LEGEND

- Transmission route
- Substations:
  - ▲ existing
  - △ proposed
- Powerstations:
  - ■ existing
  - □ proposed
- Roads (only those significant to Project are shown)

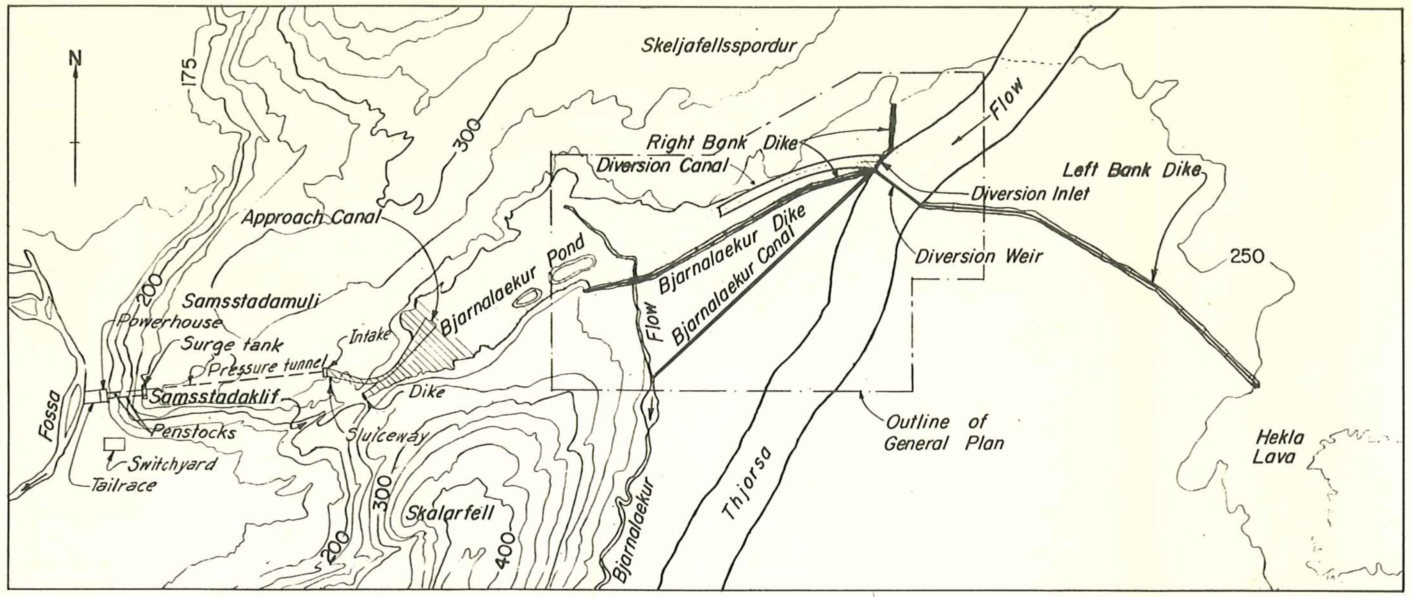
Scale 0 5 10 Kilometers

LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT
TRANSMISSION LINE ROUTE
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY HARZA ENGINEERING CO., CHICAGO APPROVED BY ______
DATE APRIL 1963 — DWG. NO. 290 P 80

BURFELL PROJECT PLAN

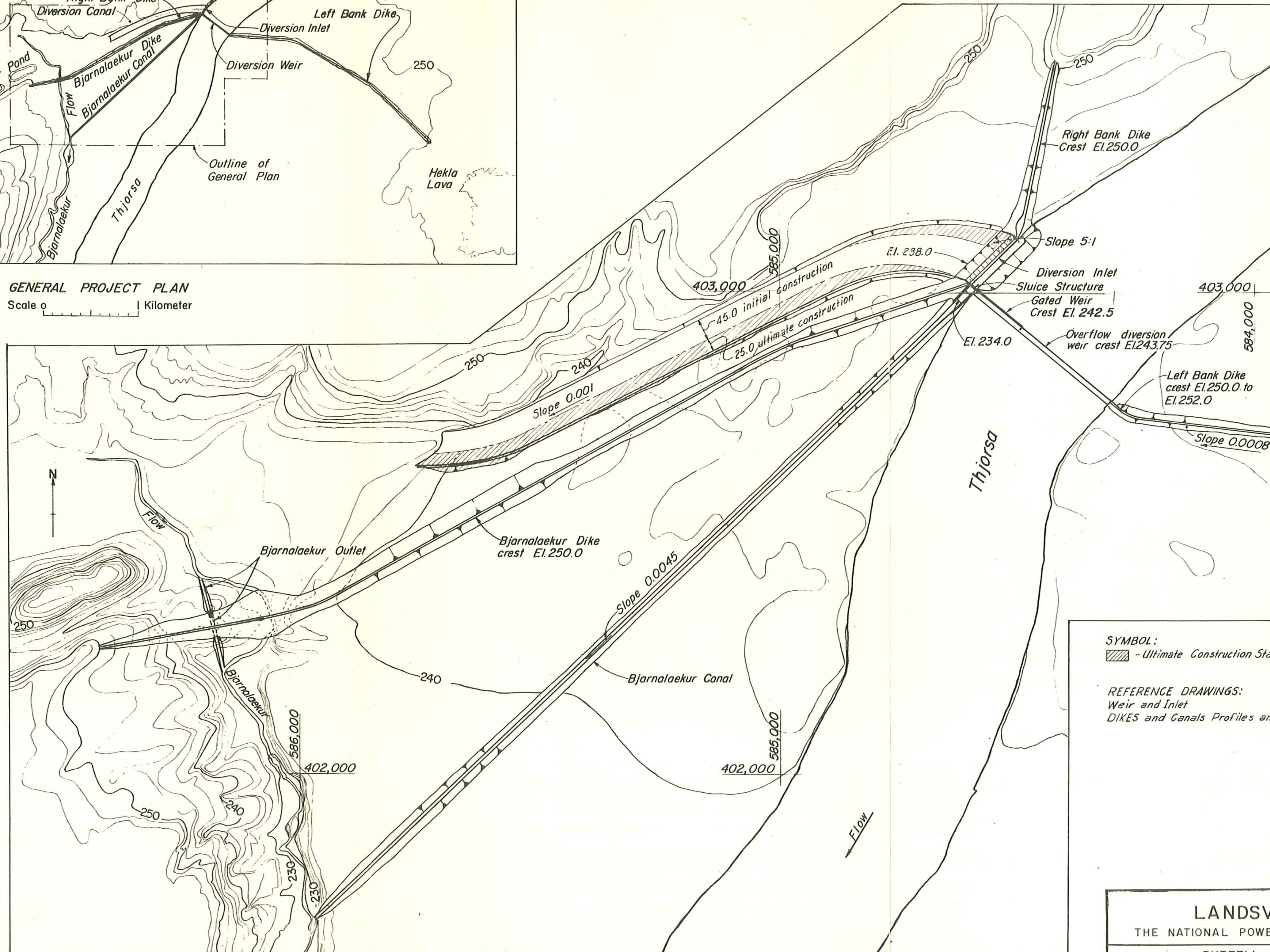
AERIAL PHOTOGRAPH

EXHIBIT 4



GENERAL PROJECT PLAN

Scale 0 — 1 Kilometer



SYMBOL:

▨ - Ultimate Construction Stage

REFERENCE DRAWINGS:

Weir and Inlet	290 SKC 13
DIKES and Canals Profiles and Sections	290 SKC 14

GENERAL PLAN OF DIVERSION STRUCTURES

Scale 0 100 200 300 400 Meters

DATE	NO	DISTRIBUTION

PRINTS

	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	SSF	Apr. 1963	VT	Apr. 1963

DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT.			
PLAN.	VT	ARE	
STAFF			CH.ENGR.

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

LANDSVIRKJUN

THE NATIONAL POWER COMPANY, ICELAND

BURFELL PROJECT

DIVERSION STRUCTURES

GENERAL PLAN

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY

HARZA ENGINEERING COMPANY

APPROVED A.P. Geuss

CHICAGO, ILLINOIS	DATE OCT. 1963	DWG. NO. 290SKC 12

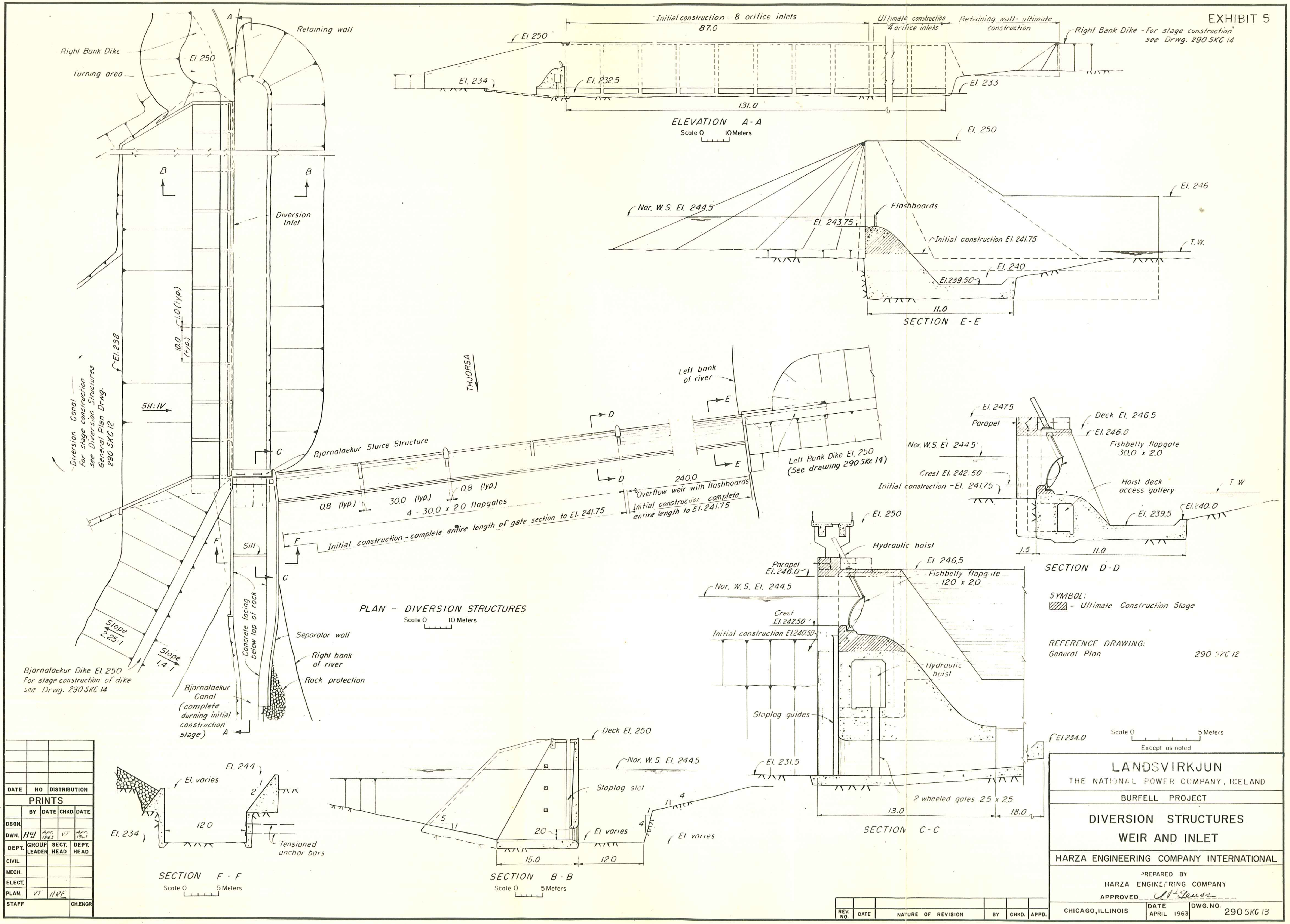
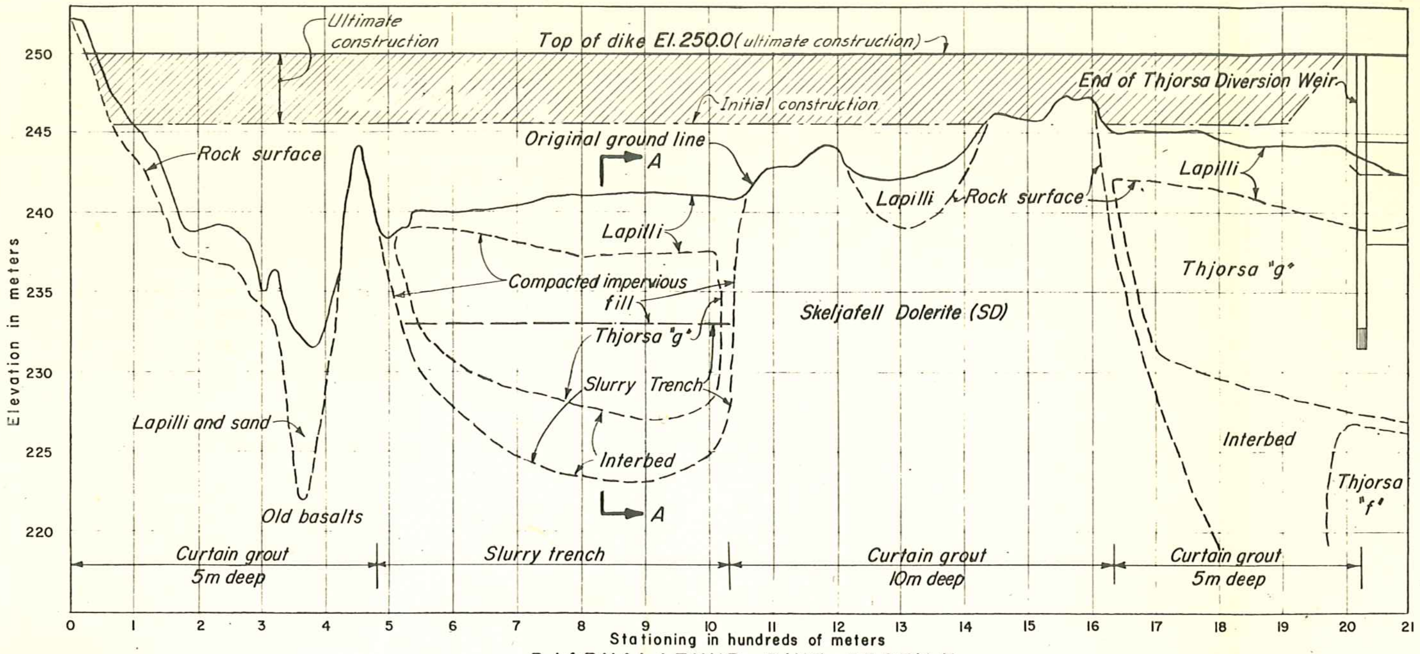
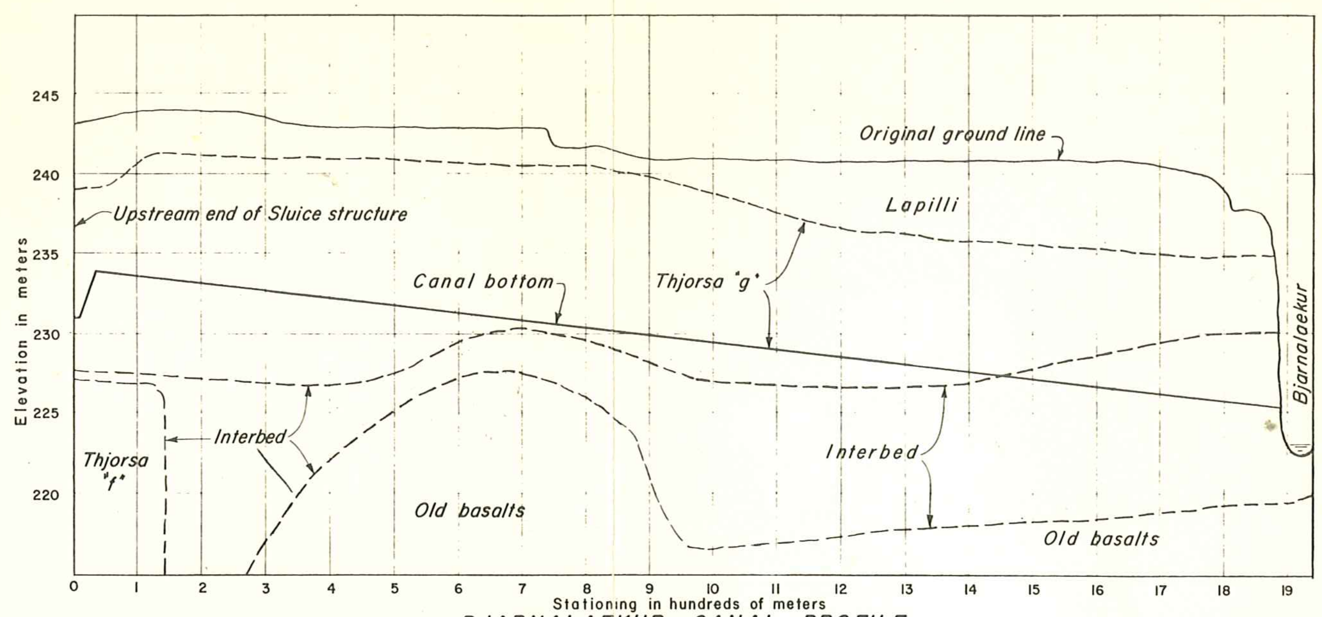


EXHIBIT 5
Initial construction – 8 orifice inlets
87.0
Ultimate construction 4 orifice inlets
Retaining wall - ultimate construction
Right Bank Dike - For stage construction see Drwg. 290 SKC 14
El. 250
El. 234
El. 232.5
El. 233
131.0
ELEVATION A-A
Scale 0 10 Meters
El. 250
El. 246
Nor. W.S. El. 244.5
Flashboards
El. 243.75
Initial construction El. 241.75
T.W.
El. 240
El. 239.50
11.0
SECTION E-E
Retaining wall
Right Bank Dike
El. 250
Turning area
B
B
Diversion Inlet
1.0 (typ.)
10.0 (typ.)
El. 238
Diversion Canal For stage construction see Diversion Structures General Plan Drwg. 290 SKC 12
5H:1V
THJORSA
Left bank of river
E
D
C
Bjarnalaekur Sluice Structure
Left Bank Dike El. 250 (See drawing 290 SKC 14)
E
D
240.0
Overflow weir with flashboards
Initial construction complete entire length to El. 241.75
0.8 (typ.)
0.8 (typ.)
30.0 (typ.)
4 - 30.0 x 2.0 flapgates
Initial construction - complete entire length of gate section to El. 241.75
F
F
Sill
C
PLAN - DIVERSION STRUCTURES
Scale 0 10 Meters
Slope 2.25:1
Slope 1.4:1
Concrete facing below top of rock
Separator wall
Right bank of river
Rock protection
Bjarnalaekur Dike El. 250 For stage construction of dike see Drwg. 290 SKC 14
Bjarnalaekur Canal (complete durning initial construction stage)
A
El. 247.5
Parapet
Deck El. 246.5
El. 246.0
Fishbelly flapgate 30.0 x 2.0
Nor. W.S. El. 244.5
Crest El. 242.50
Initial construction - El. 241.75
Hoist deck access gallery
T.W.
El. 240.0
El. 239.5
1.5
11.0
SECTION D-D
SYMBOL:
- Ultimate Construction Stage
REFERENCE DRAWING:
General Plan 290 SKC 12
El. 250
Hydraulic hoist
Parapet El. 246.0
El. 246.5
Fishbelly flapgate 12.0 x 2.0
Nor. W.S. El. 244.5
Crest El. 242.50
Initial construction El. 240.50
Hydraulic hoist
Stoplog guides
El. 234.0
El. 231.5
2 wheeled gates 2.5 x 2.5
13.0
18.0
SECTION C-C
Scale 0 5 Meters
Except as noted
El. 244
El. varies
2
El. 234
12.0
Tensioned anchor bars
SECTION F-F
Scale 0 5 Meters
Deck El. 250
Nor. W.S. El. 244.5
Stoplog slot
5
1
2.0
El. varies
4
1
4
1
El. varies
15.0
12.0
SECTION B-B
Scale 0 5 Meters
LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT
DIVERSION STRUCTURES
WEIR AND INLET
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS
DATE APRIL 1963
DWG. NO. 290 SKC 13
REV. NO.
DATE
NATURE OF REVISION
BY
CHKD.
APPD.
DATE
NO
DISTRIBUTION
PRINTS
BY
DATE
CHKD.
DATE
DSGN.
DWN.
RPJ
Apr. 1963
VT
Apr. 1963
DEPT.
GROUP LEADER
SECT. HEAD
DEPT. HEAD
CIVIL
MECH.
ELECT.
PLAN.
VT
ARE
STAFF
CH.ENGR.

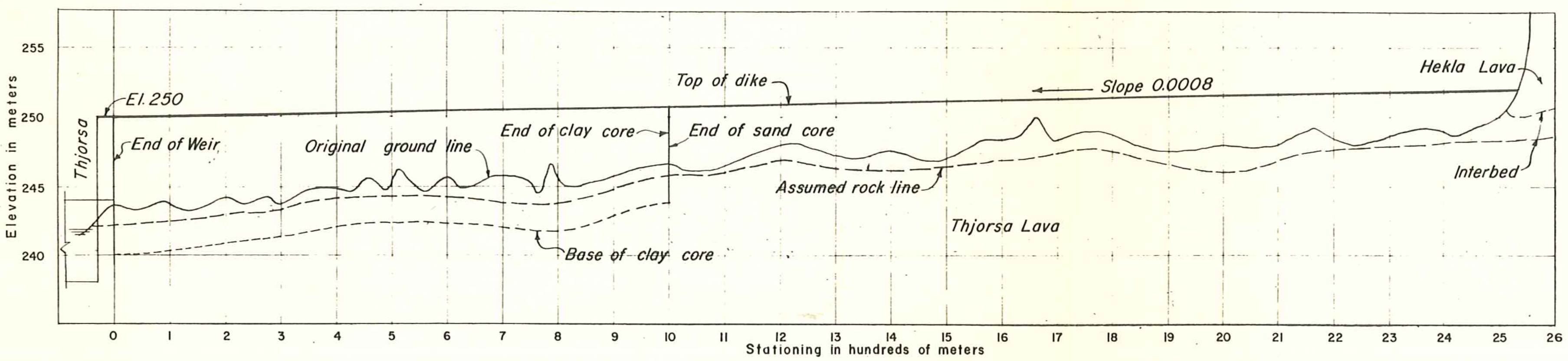
EXHIBIT 6



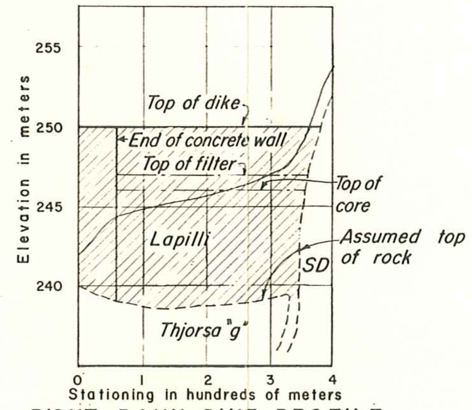
BJARNALAEKUR DIKE PROFILE



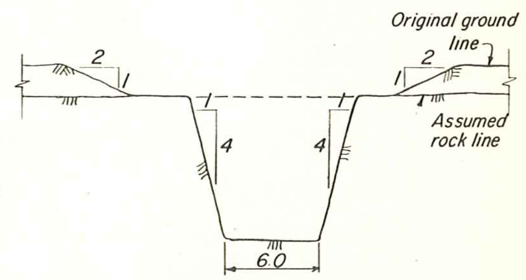
BJARNALAEKUR CANAL PROFILE
(Initial Construction)



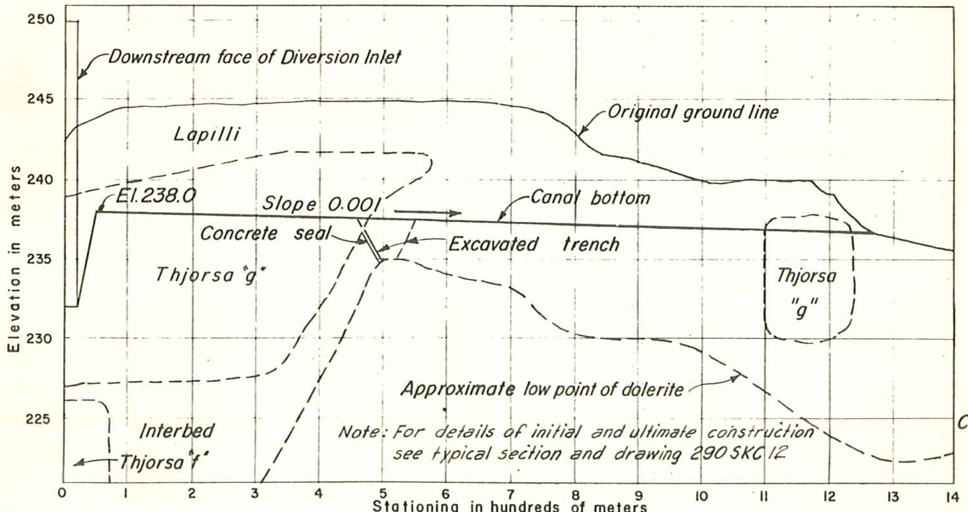
LEFT BANK DIKE PROFILE



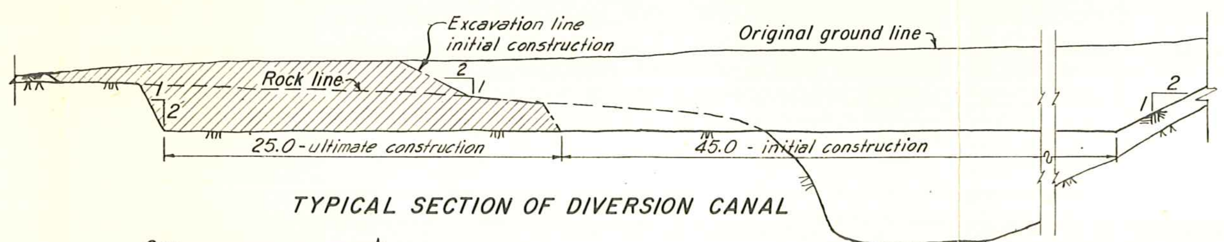
RIGHT BANK DIKE PROFILE
Built durning ultimate construction phase



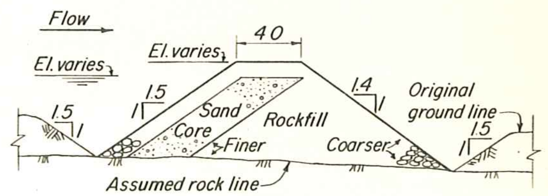
BJARNALAEKUR CANAL SECTION



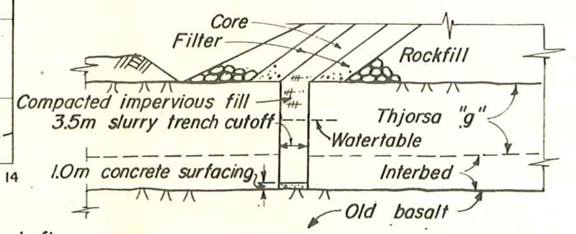
DIVERSION CANAL PROFILE



TYPICAL SECTION OF DIVERSION CANAL

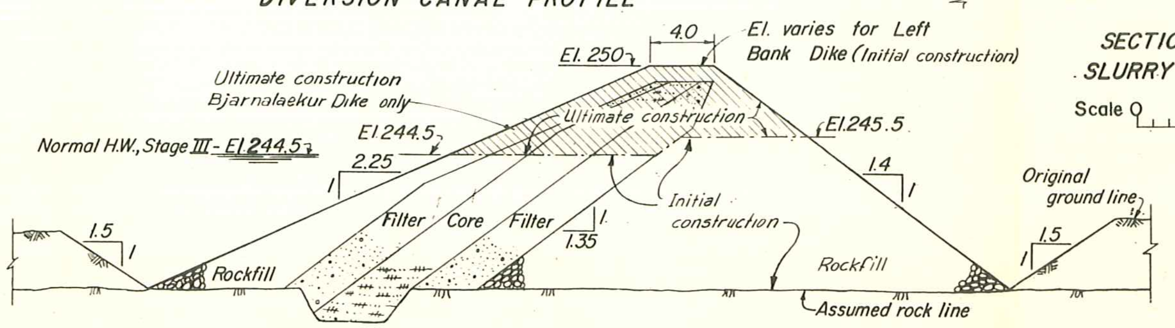


LEFT BANK DIKE SECTION
(Sta. 10+00 to end of dike)

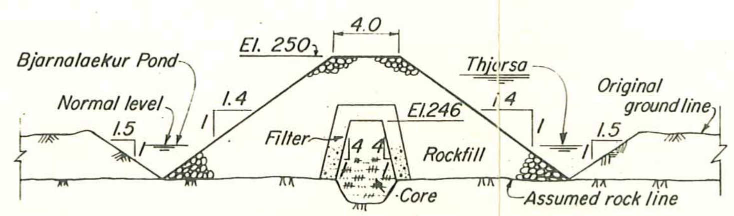


SECTION A-A
SLURRY TRENCH
Scale 0 10 Meters

Scale 0 5 10 Meters
Except as noted



SECTION OF BJARNALAEKUR DIKE AND WEST KILOMETER OF LEFT BANK DIKE



RIGHT BANK DIKE SECTION

DATE	NO	DISTRIBUTION		
PRINTS				
	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	V.E.T.	Apr. 1963	VT	Apr. 1963
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL				
MECH.				
ELECT.				
PLAN.	VT	AKF		
STAFF			CH. ENGR.	

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND

BURFELL PROJECT

DIVERSION STRUCTURES
DIKES AND CANALS
PROFILES AND SECTIONS

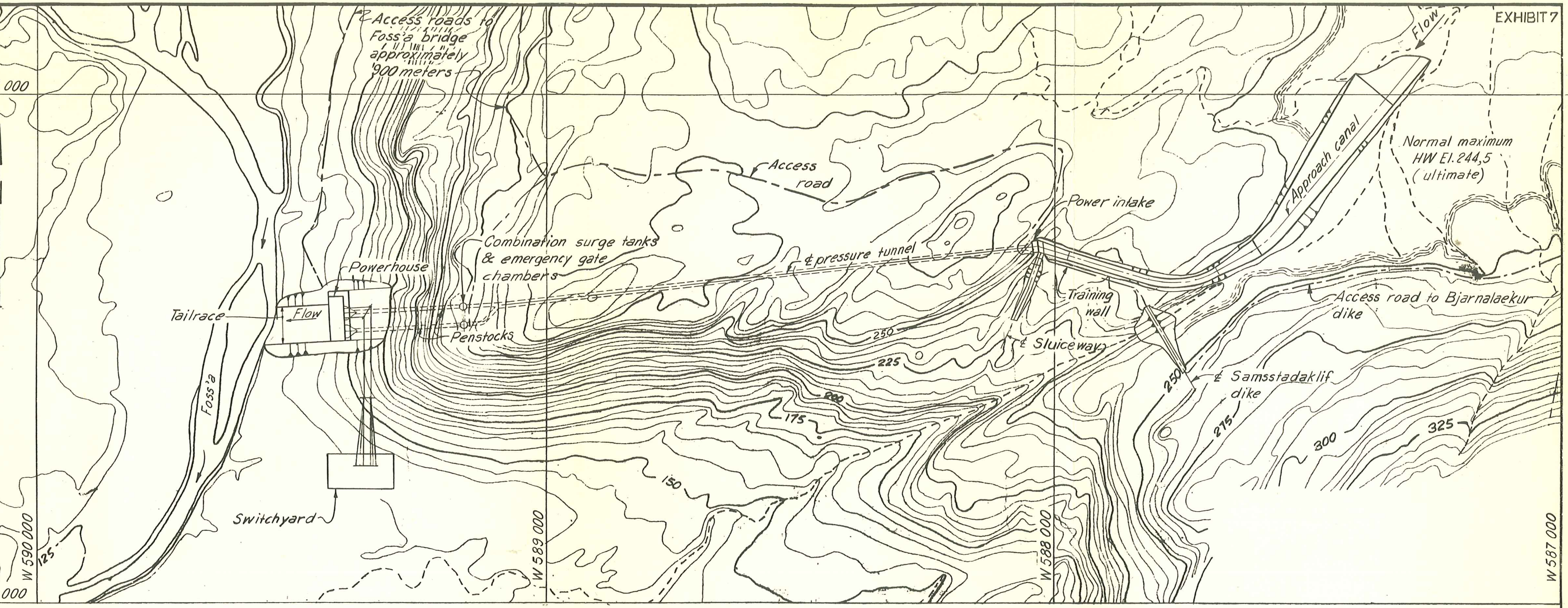
HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY
HARZA ENGINEERING COMPANY

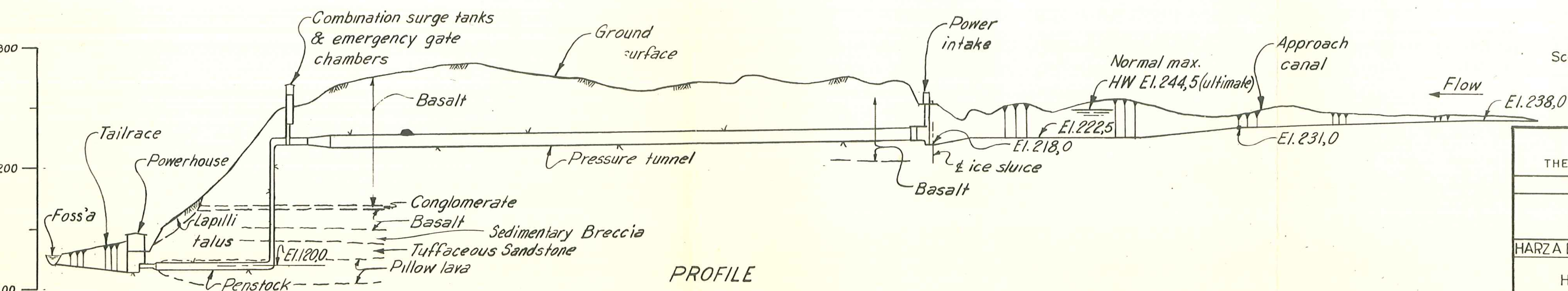
APPROVED A.P. Geuss

CHICAGO, ILLINOIS	DATE OCT. 1963	DWG. NO. 290 SKC 14

EXHIBIT 7



PLAN

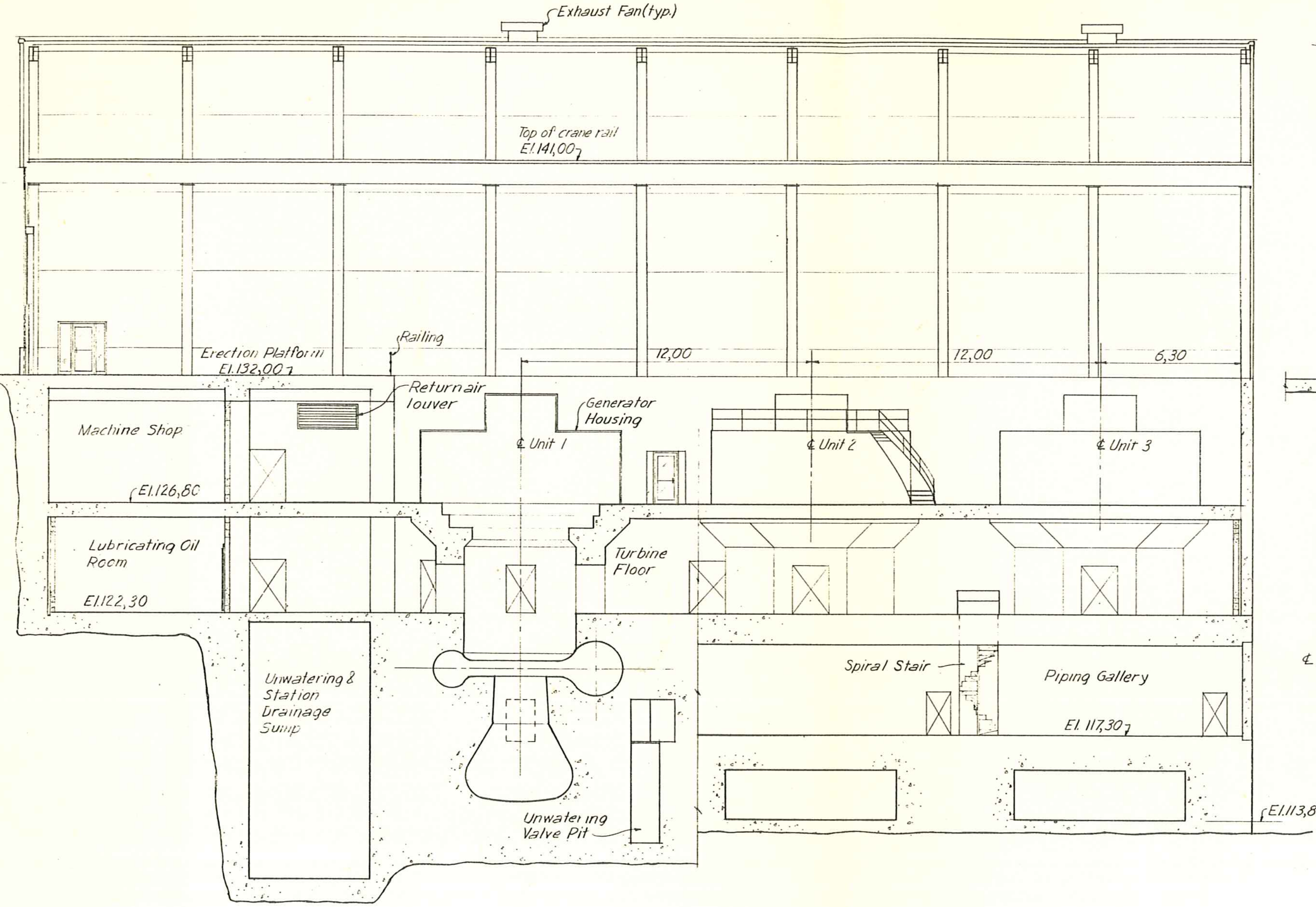


PROFILE

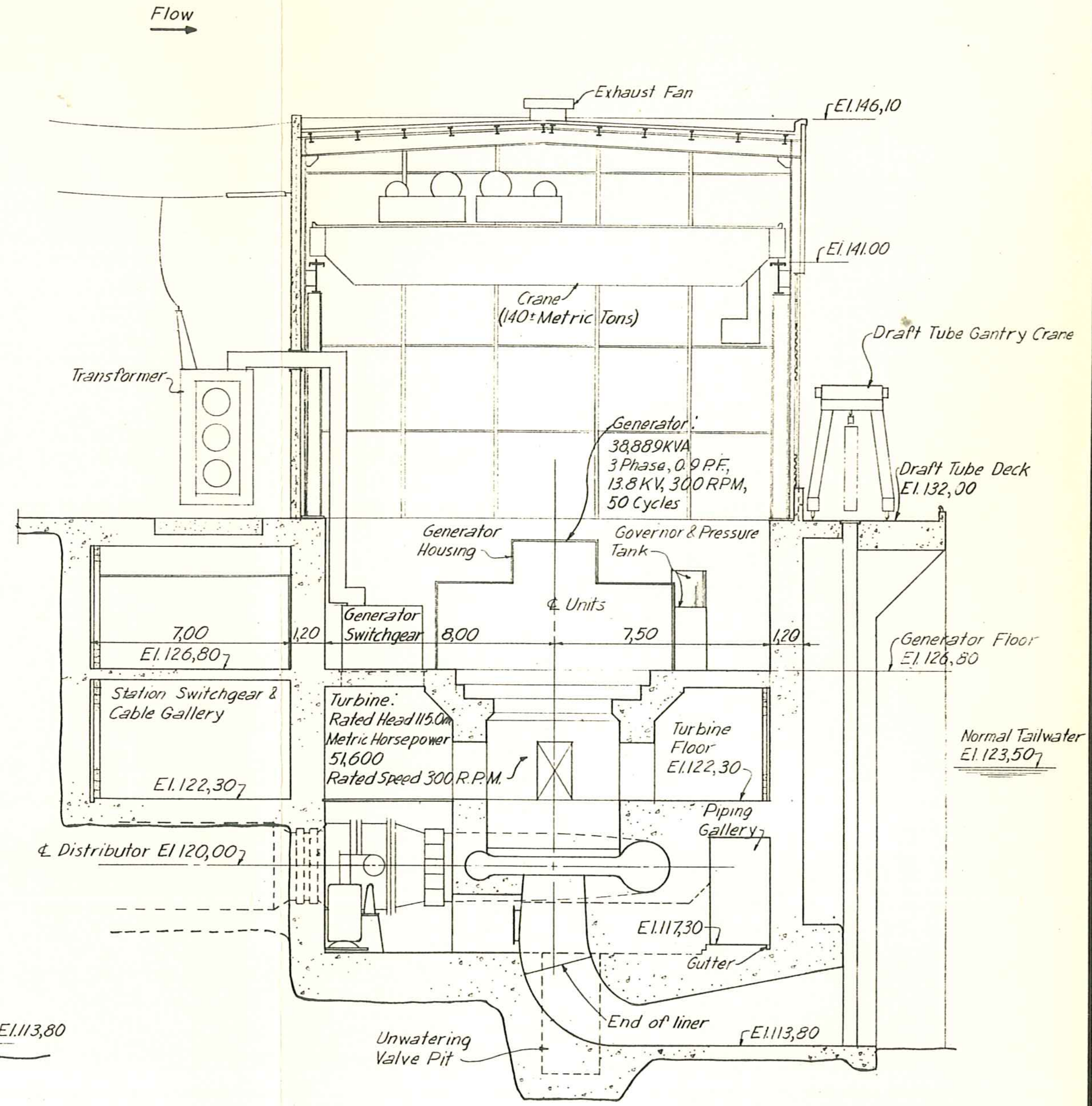
Scale 0 100 200 300 Meters
1cm = 50 meters

LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT
POWER FEATURES
GENERAL PLAN AND PROFILE
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED ________
DATE May 28, 1964 | DWG. NO. 2905KC 1R1

EXHIBIT 8



LONGITUDINAL SECTION
(Erection Bay and right 3 Units)



TRANSVERSE SECTION

Scale 0 — 5 Meters
Except as noted

DATE	NO	DISTRIBUTION

PRINTS

	BY	DATE	CHKD.	DATE
DSGN.	JJS			
DWN.	R.K.S.			

DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT.			
PLAN.			
STAFF			CH.ENGR.

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

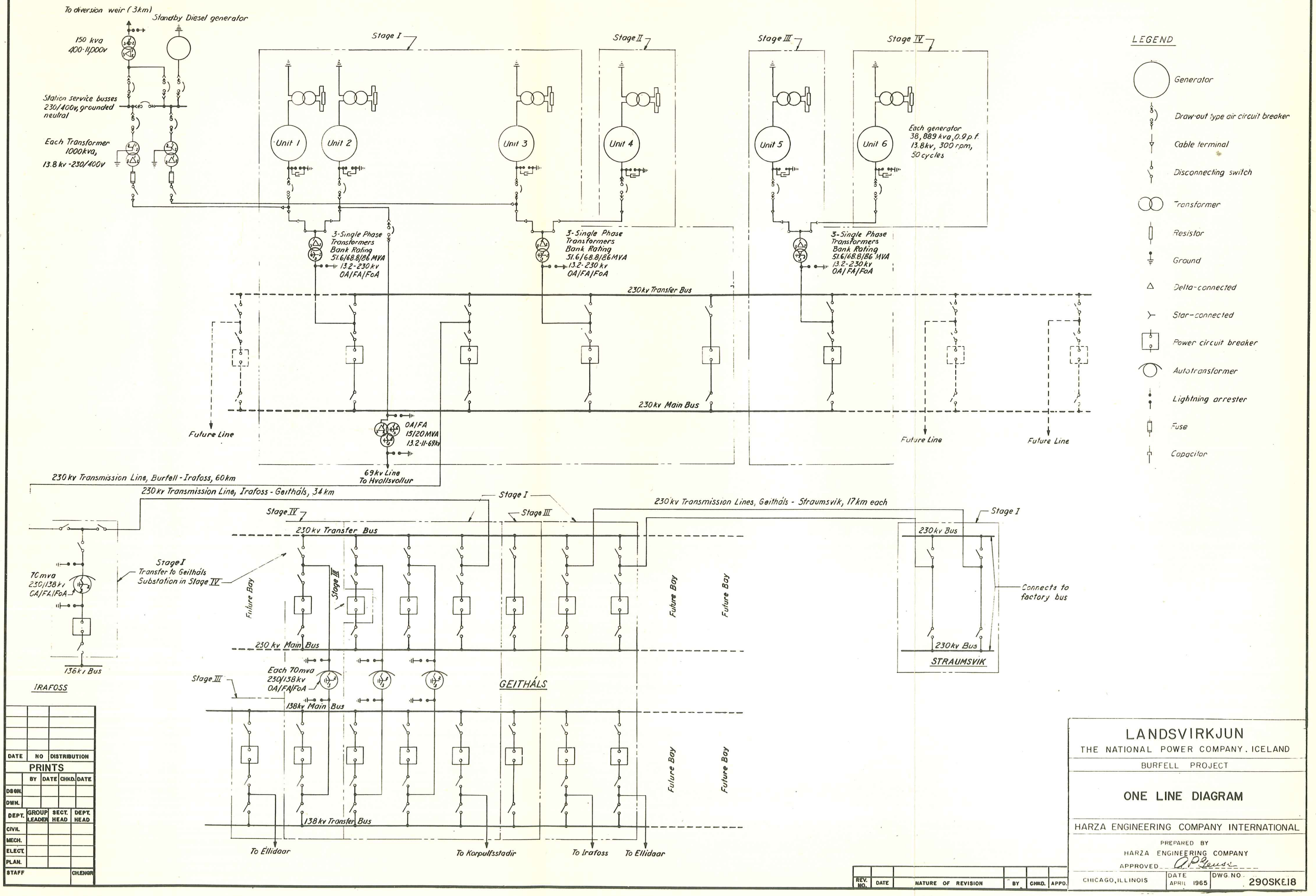
LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT

POWERHOUSE SECTIONS

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED [signature]

CHICAGO, ILLINOIS | DATE MARCH, 1965 | DWG. NO. 290 SKC 15

EXHIBIT 9


To diversion weir (3km)
Standby Diesel generator
150 kva
400-11,000v
Station service busses 230/400v, grounded neutral
Each Transformer 1000kva, 13.8kv-230/400v
Stage I
Stage II
Stage III
Stage IV
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
Unit 6
Each generator 38,889 kva, 0.9 p.f. 13.8kv, 300 rpm, 50 cycles
3-Single Phase Transformers Bank Rating 51.6/68.8/86 MVA 13.2-230 kv OA/FA/FoA
230kv Transfer Bus
230kv Main Bus
Future Line
OA/FA 15/20 MVA 13.2-11-69kv
69kv Line To Hvollsvollur
230kv Transmission Line, Burfell - Irafoss, 60km
230kv Transmission Line, Irafoss - Geithals, 34 km
230kv Transmission Lines, Geithals - Straumsvik, 17km each
Stage I Transfer to Geithals Substation in Stage IV
70mva 230/138kv OA/FA/FoA
136kv Bus
IRAFOSS
Future Bay
230kv Bus
Connects to factory bus
STRAUMSVIK
Each 70mva 230/138kv OA/FA/FoA
138kv Main Bus
GEITHÁLS
138kv Transfer Bus
To Ellidaar
To Korpulfsstadir
To Irafoss
LEGEND
Generator
Draw-out type air circuit breaker
Cable terminal
Disconnecting switch
Transformer
Resistor
Ground
Delta-connected
Star-connected
Power circuit breaker
Autotransformer
Lightning arrester
Fuse
Capacitor
DATE
NO
DISTRIBUTION
PRINTS
BY
CHKD.
DSGN.
DWN.
DEPT.
GROUP LEADER
SECT. HEAD
DEPT. HEAD
CIVIL
MECH.
ELECT.
PLAN.
STAFF
CH.ENGR.
REV. NO.
NATURE OF REVISION
APPD.
LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT
ONE LINE DIAGRAM
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED [signature]
CHICAGO, ILLINOIS
APRIL 1965
DWG. NO.
290SKE18

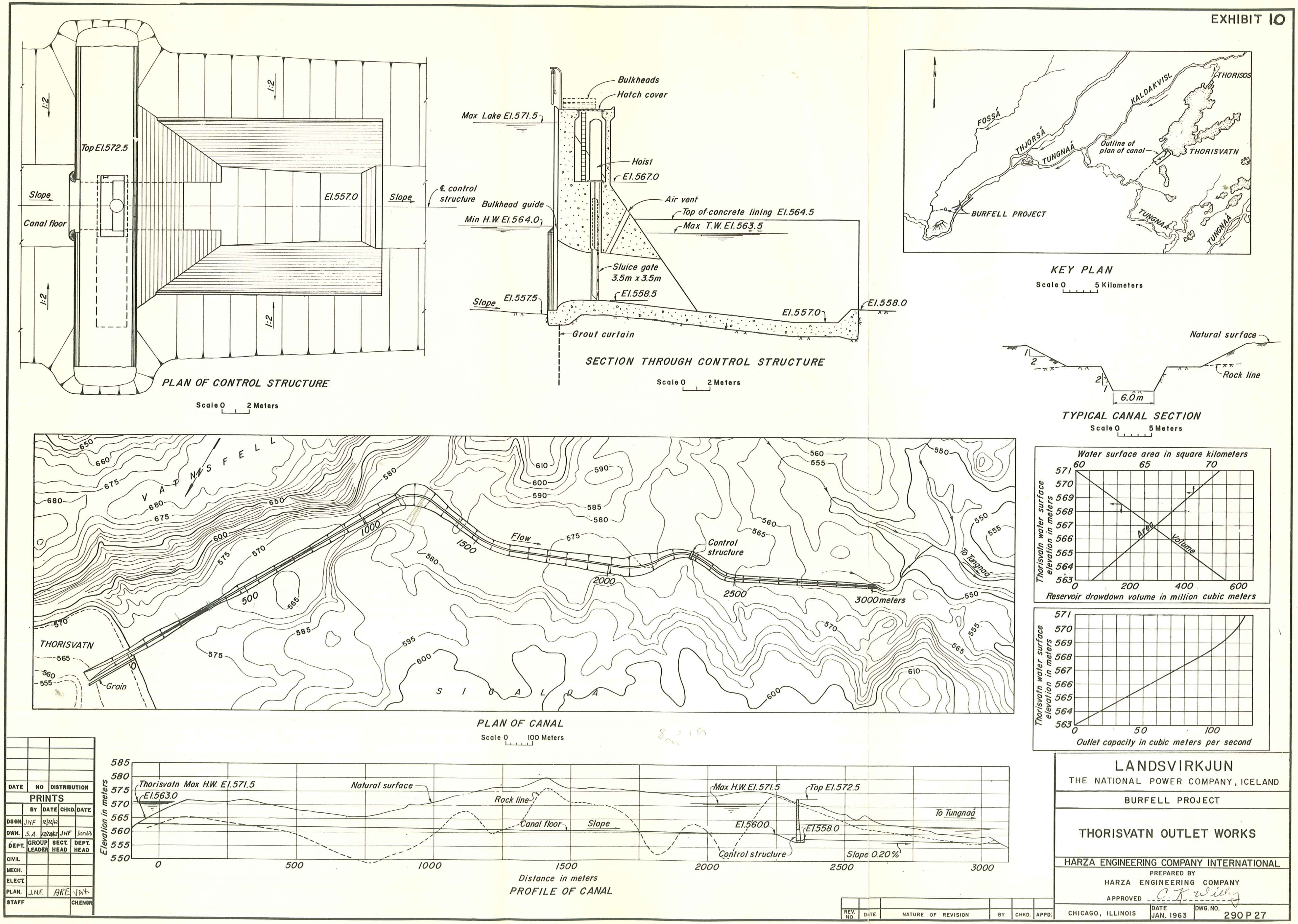


EXHIBIT 10
PLAN OF CONTROL STRUCTURE
Scale 0 2 Meters
Top El.572.5
Slope
Canal floor
El.557.0
Slope
℄ control structure
1:2
1:2
1:2
1:2
SECTION THROUGH CONTROL STRUCTURE
Scale 0 2 Meters
Bulkheads
Hatch cover
Max Lake El.571.5
Hoist
El.567.0
Bulkhead guide
Air vent
Top of concrete lining El.564.5
Min H.W. El.564.0
Max T.W. El.563.5
Sluice gate 3.5m x 3.5m
El.558.5
Slope
El.557.5
El.557.0
El.558.0
Grout curtain
KEY PLAN
Scale 0 5 Kilometers
FOSSÁ
THJORSÁ
TUNGNAÁ
KALDAKVISL
THORISOS
Outline of plan of canal
THORISVATN
BURFELL PROJECT
TUNGNAÁ
TUNGNAÁ
TYPICAL CANAL SECTION
Scale 0 5 Meters
Natural surface
Rock line
6.0m
PLAN OF CANAL
Scale 0 100 Meters
V A T N S F E L L
S I G A L D A
THORISVATN
Groin
Flow
Control structure
To Tungnaá
3000 meters
Water surface area in square kilometers
Thorisvatn water surface elevation in meters
Area
Volume
Reservoir drawdown volume in million cubic meters
Thorisvatn water surface elevation in meters
Outlet capacity in cubic meters per second
PROFILE OF CANAL
Elevation in meters
Distance in meters
Thorisvatn Max H.W. El.571.5
El.563.0
Natural surface
Rock line
Canal floor
Slope
Max H.W. El.571.5
Top El.572.5
El.5600
El.558.0
Control structure
Slope 0.20%
To Tungnaá
LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT
THORISVATN OUTLET WORKS
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS
DATE JAN. 1963
DWG. NO. 290 P 27
REV. NO.
DATE
NATURE OF REVISION
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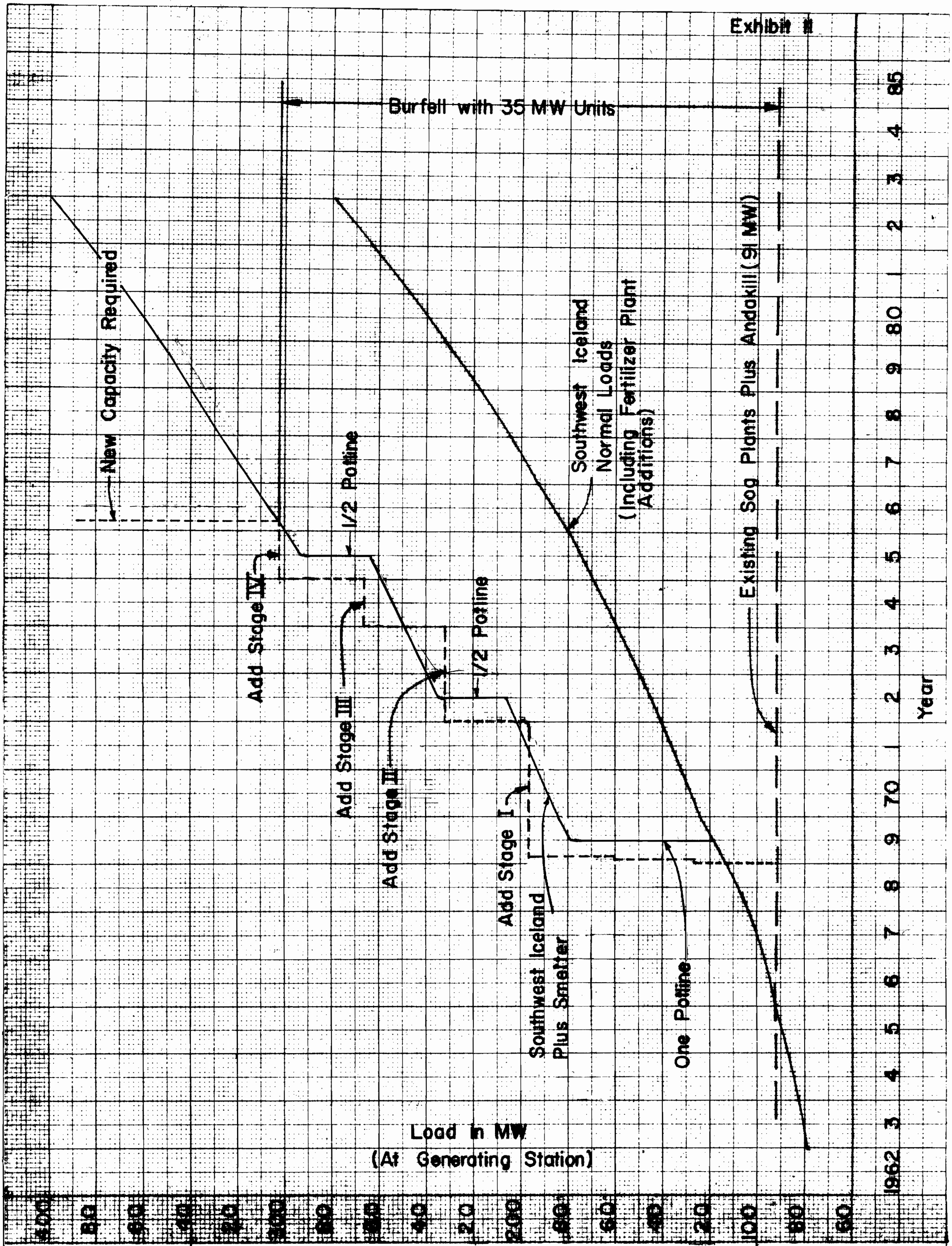
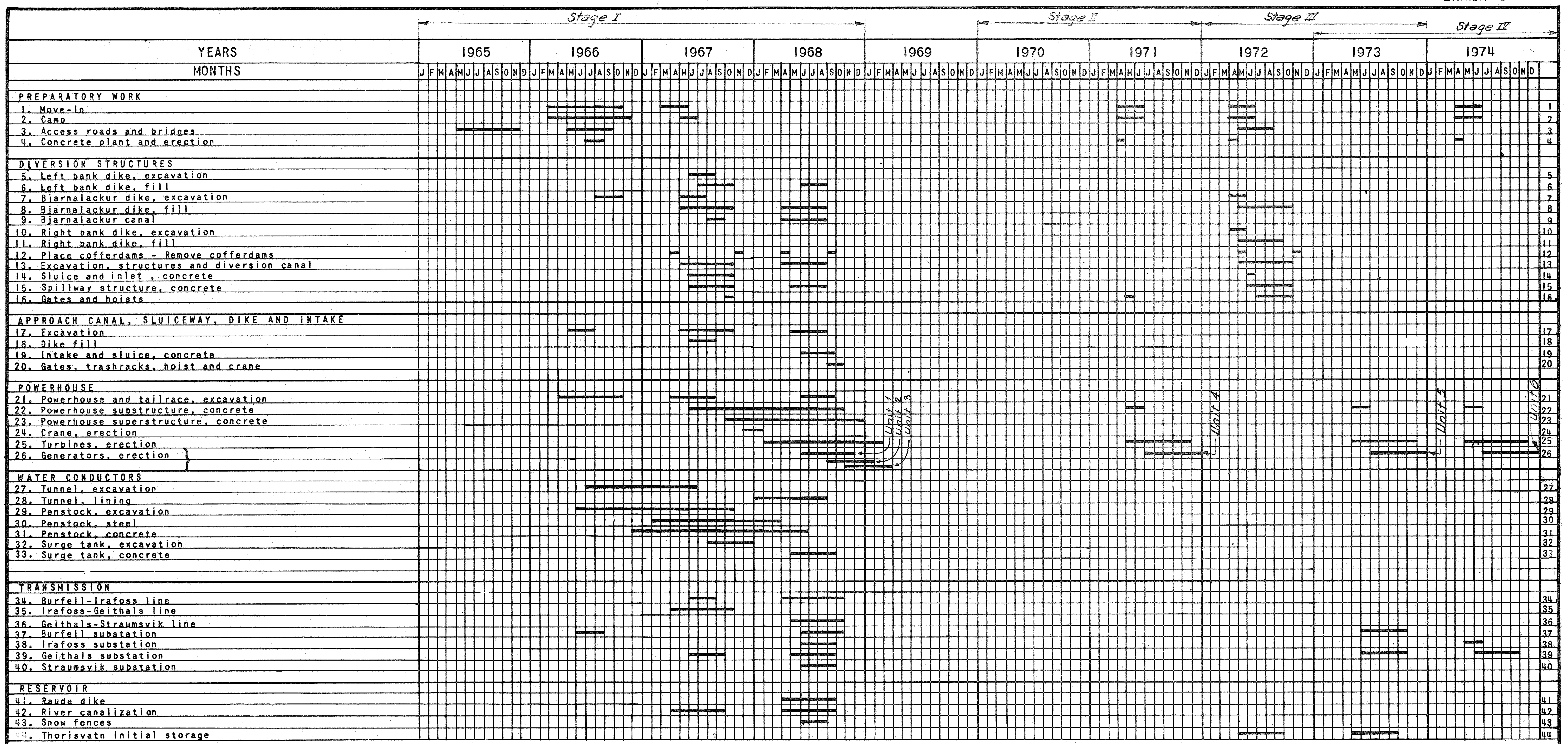


HARZA ENGINEERING COMPANY INTERNATIONAL	Estimated Loads and Resources Southwest Iceland with Aluminium Smelter Burfell Project with 35 MW Units	MARCH 31, 1965 290 SKC 17

EXHIBIT 12



LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT

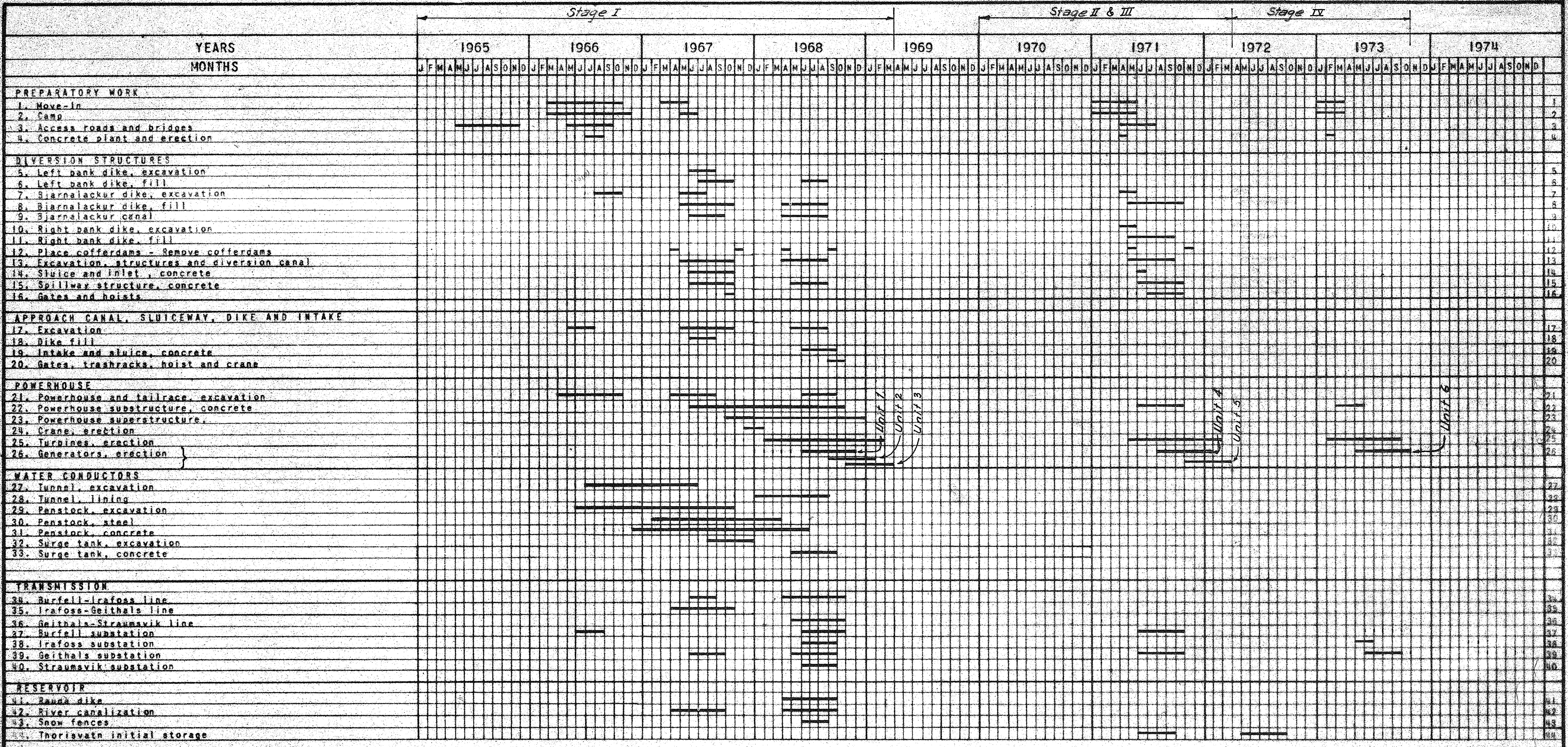
CONSTRUCTION SCHEDULE

HARZA ENGINEERING COMPANY INTERNATIONAL

HARZA ENGINEERING CO., CHICAGO
APPROVED C. K. Willey

DATE APRIL, 1965 | DWG. NO. 290 SKC19

EXHIBIT 12 A



LANDSVIRKJUN
THE NATIONAL POWER COMPANY, ICELAND
BURFELL PROJECT

CONSTRUCTION SCHEDULE

HARZA ENGINEERING COMPANY INTERNATIONAL

HARZA ENGINEERING CO., CHICAGO
APPROVED C. K. Willey

DATE APRIL, 1965 DWG. NO. 290 SKC 20

BURFELL HYDROELECTRIC PROJECT

PROJECT SCHEDULED WITHOUT ALUMINIUM SMELTER FOR SOUTHWEST ICELAND LOADS ONLY

CONSTRUCTION COST ESTIMATE SUMMARY

BY STAGES DIVIDED BETWEEN DOMESTIC AND FOREIGN CURRENCY

IN UNITED STATES DOLLARS

EXHIBIT 13A

	Stage I - Two 35 MW Units			Stage IA - One 35 MW Unit			Stage II - One 35 MW Unit			Stage III - One 35 MW Unit			Stage IV - One 35 MW Unit			Project Totals		
	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total
Production Plant																		
Power Plant, Structures & Improvements																		
Power Station	584,000	639,000	1,223,000	210,000	253,000	463,000	165,000	208,000	373,000	165,000	208,000	373,000	137,000	176,000	313,000	1,261,000	1,484,000	2,745,000
Station Yard	6,000	6,000	12,000	-	-	-	-	-	-	-	-	-	-	-	-	6,000	6,000	12,000
Subtotal Power Plant Structures & Improvements	590,000	645,000	1,235,000	210,000	253,000	463,000	165,000	208,000	373,000	165,000	208,000	373,000	137,000	176,000	313,000	1,267,000	1,490,000	2,757,000
Reservoir, Dams & Waterways																		
Burfell Reservoir	152,000	232,000	384,000	-	-	-	-	-	-	-	-	-	-	-	-	152,000	232,000	384,000
Bjarnalaekur Dike	535,000	579,000	1,114,000	-	-	-	-	-	-	84,000	92,000	176,000	-	-	-	619,000	671,000	1,290,000
Thjorsa Diversion Dikes	273,000	322,000	595,000	-	-	-	-	-	-	66,000	78,000	144,000	-	-	-	339,000	400,000	739,000
Diversion Canal	146,000	172,000	318,000	-	-	-	118,000	136,000	254,000	188,000	220,000	408,000	-	-	-	452,000	528,000	980,000
Bjarnalaekur Canal	224,000	261,000	485,000	-	-	-	-	-	-	-	-	-	-	-	-	224,000	261,000	485,000
Diversion Weir & Inlet	505,000	627,000	1,132,000	-	-	-	171,000	209,000	380,000	283,000	419,000	702,000	-	-	-	959,000	1,255,000	2,214,000
Approach Canal	564,000	609,000	1,173,000	-	-	-	-	-	-	-	-	-	-	-	-	564,000	609,000	1,173,000
Samsstadklif Sluiceway	72,000	101,000	173,000	-	-	-	-	-	-	-	-	-	-	-	-	72,000	101,000	173,000
Samsstadklif Dike	47,000	47,000	94,000	-	-	-	-	-	-	-	-	-	-	-	-	47,000	47,000	94,000
Intake	177,000	308,000	485,000	-	-	-	-	-	-	-	-	-	-	-	-	177,000	308,000	485,000
Penstocks and Tunnels	1,050,000	1,650,000	2,700,000	-	-	-	315,000	565,000	880,000	-	-	-	-	-	-	1,365,000	2,215.000	3,580,000
Surge Chambers	182,000	310,000	492,000	-	-	-	46,000	120,000	166,000	-	-	-	-	-	-	228,000	430,000	658,000
Tailrace Canal	65,000	75,000	140,000	21,700	24,800	46,500	21,200	24,600	45,800	21,200	24,600	45,800	-	-	-	129,100	149,000	278,100
Subtotal Reservoir, Dams & Waterways	3,992,000	5,293,000	9,285,000	21,700	24,800	46,500	671,200	1,054,600	1,725,800	642,200	833,600	1,475,800	-	-	-	5,327,100	7,206,000	12,533,100
Turbines, Governors & Generators	142,000	1,260,000	1,402,000	76,000	630,000	706,000	76,000	630,000	706,000	76,000	630,000	706,000	76,000	630,000	706,000	446,000	3,780,000	4,226,000
Accessory Electrical Equipment	81,000	293,000	374,000	37,000	134,000	171,000	39,000	137,000	176,000	39,000	137,000	176,000	39,000	137,000	176,000	235,000	838,000	1,073,000
Miscellaneous Mechanical Equipment	68,000	271,000	339,000	15,000	57,000	72,000	15,000	57,000	72,000	15,000	57,000	72,000	15,000	57,000	72,000	128,000	499,000	627,000
Operators Village, Access & General Plant	109,000	183,000	292,000	22,000	23,000	45,000	11,000	11,000	22,000	11,000	11,000	22,000	11,000	14,000	25,000	164,000	242,000	406,000
Roads and Bridges	500,000	0	500,000	0	0	0	0	0	0	100,000	0	100,000	-	-	-	600,000	-	600,000
Subtotal Production Plant	5,482,000	7,945,000	13,427,000	381,700	1,121,800	1,503,600	977,200	2,097,600	3,074,800	1,048,200	1,876,600	2,924,800	278,000	1,014,000	1,292,000	8,167,100	14,055,000	22,222,100
Transmission Plant																		
Burfell Step-Up Substation	163,000	510,000	673,000	34,000	223,000	257,000	-	-	-	55,000	253,000	308,000	-	-	-	252,000	986,000	1,238,000
Geithals Receiving Substation	141,000	554,000	695,000	58,000	237,000	295,000	-	-	-	10,000	35,000	45,000	26,000	56,000	82,000	235,000	882,000	1,117,000
Irafoss Substation	0	0	0	31,000	188,000	219,000	-	-	-	-	-	-	-	-	-	31,000	188,000	219,000
Transmission Line																		
Burfell-Irafoss	369,000	554,000	923,000	-	-	-	-	-	-	-	-	-	-	-	-	369,000	554,000	923,000
Irafoss to Geithals	209,000	314,000	523,000	-	-	-	-	-	-	-	-	-	-	-	-	209,000	314,000	523,000
Subtotal Transmission Plant	882,000	1,932,000	2,814,000	123,000	648,000	771,000	-	-	-	65,000	288,000	353,000	26,000	56,000	82,000	1,096,000	2,924,000	4,020,000
Subtotal Direct Construction Cost	6,364,000	9,877,000	16,241,000	504,700	1,769,800	2,274,500	977,200	2,097,600	3,074,800	1,113,200	2,164,600	3,277,800	304,000	1,070,000	1,374,000	9,263,100	16,979,000	26,242,100
Contingencies	1,266,000	1,223,000	2,489,000	95,300	180,200	275,500	192,800	202,400	395,200	226,800	235,400	462,200	56,000	80,000	136,000	1,836,900	1,921,000	3,757,900
Engineering, Supervision & Overhead	600,000	1,270,000	1,870,000	100,000	150,000	250,000	150,000	200,000	350,000	160,000	200,000	360,000	50,000	100,000	150,000	1,060,000	1,920,000	2,980,000
Subtotal	8,230,000	12,370,000	20,600,000	700,000	2,100,000	2,800,000	1,320,000	2,500,000	3,820,000	1,500,000	2,600,000	4,100,000	410,000	1,250,000	1,660,000	12,160,000	20,820,000	32,980,000
Thorisvatn Initial Storage	-	-	-	-	-	-	-	-	-	1,000,000	1,000,000	2,000,000	-	-	-	1,000,000	1,000,000	2,000,000
Preliminary costs	800,000	-	800,000	-	-	-	-	-	-	-	-	-	-	-	-	800,000	-	800,000
Estimated Added Cost Due to incremental Construction	0	0	0	100,000	100,000	200,000	100,000	180,000	280,000	100,000	200,000	300,000	40,000	100,000	140,000	340,000	580,000	920,000
Total Construction Cost	9,030,000	12,370,000	21,400,000	800,000	2,200,000	3,000,000	1,420,000	2,680,000	4,100,000	2,600,000	3,800,000	6,409,000	450,000	1,350,000	1,800,000	14,300,000	22,400,000	36,700,000

Note: Estimates do not include import duties and taxes or interest during construction.

BURFELL PROJECT - COST ESTIMATE
SUMMARY - STAGE I

Item	Total Exclusive Duties, Taxes and Interest (US Dollars)	Domestic Currency Requirements (US Dollars)	Foreign Currency Requirements (US Dollars)
PRODUCTION PLANT			
Power Plant, Structures & Improvements			
Power Station	2,514,000	1,190,000	1,324,000
Station Yard	12,000	6,000	6,000
Subtotal Power Plant, Structures & Improvements	2,526,000	1,196,000	1,330,000
Reservoir, Dams and Waterways			
Burfell Reservoir	384,000	152,000	232,000
Bjarnalækur Dike	1,114,000	535,000	579,000
Thorsa Diversion Dikes	595,000	273,000	322,000
Diversion Canal	572,000	264,000	308,000
Bjarnalækur Canal	485,000	224,000	261,000
Diversion Weir & Inlet (12 openings)	1,804,000	806,000	998,000
Approach Canal	1,173,000	564,000	609,000
Samsstadaklif Sluiceway	173,000	72,000	101,000
Samsstadaklif Dike	94,000	47,000	47,000
Intake	485,000	177,000	308,000
Penstocks and Tunnels	3,574,000	1,390,000	2,184,000
Surge Chamber	492,000	182,000	310,000
Tailrace Canal	278,000	129,000	149,000
Subtotal Reservoir, Dams & Waterways	11,223,000	4,815,000	6,408,000
Turbines, Governors & Generators	2,117,000	212,000	1,905,000
Accessory Electrical Equipment	544,000	118,000	426,000
Miscellaneous Mechanical Equipment	409,000	82,000	327,000
Operators' Village, Access & General Plant	292,000	109,000	183,000
Roads and Bridges	500,000	500,000	---
SUBTOTAL PRODUCTION PLANT	17,611,000	7,032,000	10,579,000
Transmission Plant			
Burfell Step-up Substation	930,000	197,000	733,000
Geithals Receiving Substation	972,000	190,000	782,000
Irafoss Substation	219,000	31,000	188,000
Straumsvik Substation	58,000	13,000	45,000
Transmission Line			
Burfell to Irafoss (1 circuit) 60 km	923,000	369,000	554,000
Irafoss to Geithals (1 circuit) 34 km	523,000	209,000	314,000
Geithals to Straumsvik (2 circuits) 17 km	523,000	209,000	314,000
Subtotal Transmission Plant	4,148,000	1,218,000	2,930,000
SUBTOTAL DIRECT CONSTRUCTION COST	21,759,000	8,250,000	13,509,000
Contingencies:			
Construction Items (16,753,000)	2,960,000	1,500,000	1,460,000
Equipment Items (5,006,000)	355,000	150,000	205,000
	25,074,000	9,900,000	15,174,000
Engineering Supervision & Overhead	2,500,000	800,000	1,700,000
Subtotal	27,574,000	10,700,000	16,874,000
Preliminary Costs	800,000	800,000	---
TOTAL CONSTRUCTION COST	28,374,000	11,500,000	16,874,000

BURFELL PROJECT - COST ESTIMATE

SUMMARY - STAGE II

EXHIBIT 13
Sheet 2 of 4

Item	Total Exclusive Duties, Taxes and Interest (US Dollars)	Domestic Currency Requirements (US Dollars)	Foreign Currency Requirements (US Dollars)
PRODUCTION PLANT			
Power Plant, Structures & Improvements			
Power Station	49,000	22,000	27,000
Station Yard	----	----	----
Subtotal Power Plant, Structures & Improvements	49,000	22,000	27,000
Reservoir, Dams and Waterways			
Burfell Reservoir	----	----	----
Bjarnalækur Dike	----	----	----
Thorsa Diversion Dikes	----	----	----
Diversion Canal	----	----	----
Bjarnalækur Canal	----	----	----
Diversion Weir and Inlet	----	----	----
Approach Canal	----	----	----
Samsstadaklif Sluiceway	----	----	----
Samsstadaklif Dike	----	----	----
Intake	----	----	----
Penstock and Tunnels	----	----	----
Surge Chamber	166,000	46,000	120,000
Tailrace Canal	----	----	----
Subtotal Reservoir, Dams & Waterways	166,000	46,000	120,000
Turbines, Governors & Generators	706,000	76,000	630,000
Accessory Electrical Equipment	171,000	37,000	134,000
Miscellaneous Mechanical Equipment	72,000	15,000	57,000
Operators' Village, Access & General	45,000	22,000	23,000
SUBTOTAL PRODUCTION PLANT	1,209,000	218,000	991,000
Transmission Plant			
Burfell Step-up Substation	----	----	----
Transmission Line, Burfell-Reykjavik	----	----	----
Geithals Receiving Substation	----	----	----
Subtotal Transmission Plant	----	----	----
SUBTOTAL DIRECT CONSTRUCTION COST	1,209,000	218,000	991,000
Contingencies:			
Construction Items (260,000)	50,000	45,000	5,000
Equipment Items (949,000)	69,000	30,000	39,000
	1,328,000	293,000	1,035,000
Engineering, Supervision & Overhead	170,000	50,000	120,000
Estimated Added Cost Due to Incremental Construction	120,000	43,000	77,000
TOTAL CONSTRUCTION COST	1,618,000	386,000	1,232,000

BURFELL PROJECT - COST ESTIMATE

SUMMARY - STAGE III

EXHIBIT 13
Sheet 3 of 4

Item	Total Exclusive Duties, Taxes and Interest (US Dollars)	Domestic Currency Requirements (US Dollars)	Foreign Currency Requirements (US Dollars)
PRODUCTION PLANT			
Power Plant, Structures & Improvements			
Power Station	49,000	22,000	27,000
Station Yard	----	----	----
Subtotal Power Plant, Structures & Improvements	49,000	22,000	27,000
Reservoir, Dam & Waterways			
Burfell Reservoir	----	----	----
Bjarnalækur Dike	176,000	84,000	92,000
Thorsa Diversion Dikes	144,000	66,000	78,000
Diversion Canal	408,000	188,000	220,000
Bjarnalækur Canal	----	----	----
Diversion Weir	410,000	153,000	257,000
Approach Canal	----	----	----
Samsstadaklif Sluiceway	----	----	----
Samsstadaklif Dike	----	----	----
Intake	----	----	----
Penstock and Tunnels	----	----	----
Surge Chamber	----	----	----
Tilrace Canal	----	----	----
Subtotal Reservoir, Dam & Waterways	1,138,000	491,000	647,000
Turbines, Governors & Generators	706,000	76,000	630,000
Accessory Electrical Equipment	176,000	39,000	137,000
Miscellaneous Mechanical Equipment	72,000	15,000	57,000
Operators' Village, Access & General	22,000	11,000	11,000
Roads and Bridges	100,000	100,000	----
SUBTOTAL PRODUCTION PLANT	2,263,000	754,000	1,509,000
Transmission Plant			
Burfell Step-up Substation	308,000	55,000	253,000
Transmission Line, Burfell-Reykjavik	----	----	----
Geithals Receiving Substation	232,000	52,000	180,000
Subtotal Transmission Plant	540,000	107,000	433,000
SUBTOTAL DIRECT CONSTRUCTION COST	2,803,000	861,000	1,942,000
Contingencies:			
Construction Items (1,359,000)	236,000	112,000	124,000
Equipment Items (1,444,000)	103,000	43,000	60,000
	3,142,000	1,016,000	2,126,000
Engineering, Supervision & Overhead	355,000	113,000	242,000
Estimated Added Cost Due to Incremental Construction	358,000	179,000	179,000
Thorisvatn Initial Storage *	2,000,000	1,000,000	1,000,000
TOTAL CONSTRUCTION COST	5,855,000	2,308,000	3,547,000

* Includes Contingencies, Engineering, Overhead but not Interest during construction.

BURFELL PROJECT - COST ESTIMATE

SUMMARY - STAGE IV

Item	Total Exclusive Duties, Taxes and Interest (US Dollars)	Domestic Currency Requirements (US Dollars)	Foreign Currency Requirements (US Dollars)
PRODUCTION PLANT			
Power Plant, Structures & Improvements			
Power Station	49,000	22,000	27,000
Station Yard	----	----	----
Subtotal Power Plant, Structures & Improvements	49,000	22,000	27,000
Reservoir, Dams and Waterways			
Burfell Reservoir	----	----	----
Bjarnalækur Dike	----	----	----
Thorsa Diversion Dike	----	----	----
Diversion Canal	----	----	----
Bjarnalækur Canal	----	----	----
Diversion Weir	----	----	----
Approach Canal	----	----	----
Samsstadaklif Sluiceway	----	----	----
Samsstadaklit Dike	----	----	----
Intake	----	----	----
Penstock and Tunnels	----	----	----
Surge Chamber	----	----	----
Tailrace Canal	----	----	----
Subtotal Reservoir, Dams & Waterways	----	----	----
Turbines, Governors & Generators	706,000	76,000	630,000
Accessory Electrical Equipment	176,000	39,000	137,000
Miscellaneous Mechanical Equipment	72,000	15,000	57,000
Operators' Village, Access and General	25,000	11,000	14,000
Roads and Bridges	----	----	----
SUBTOTAL PRODUCTION PLANT	1,028,000	163,000	865,000
Transmission Plant			
Burfell Step-up Substation	----	----	----
Transmission Line, Burfell-Reykjavik	----	----	----
Geithals Receiving Substation	82,000	26,000	56,000
Subtotal Transmission Plant	82,000	26,000	56,000
SUBTOTAL DIRECT CONSTRUCTION COST	1,110,000	189,000	921,000
Contingencies:			
Construction Items (156,000)	34,000	30,000	4,000
Equipment Items (954,000)	72,000	27,000	45,000
	1,216,000	246,000	970,000
Engineering, Supervision & Overhead	120,000	30,000	90,000
Estimated Added Cost Due to Incremental Construction	70,000	35,000	35,000
TOTAL CONSTRUCTION COST	1,406,000	311,000	1,095,000

T H E   A P P E N D I C E S

APPENDIX A

BURFELL HYDROELECTRIC PROJECT

SUMMARY OF ENGINEERING REPORTS

Prepared by

HARZA ENGINEERING COMPANY INTERNATIONAL

Report No. 1 - Advisory Report - Hydroelectric Power Resources - Hvita and Thjorsa River Systems - Southwest Iceland, March 1960.

This report identified Burfell as a potential large hydroelectric project on the Thjorsa. The development suggested therein would have provided seasonal storage. The report served to initiate field investigations in the summers of 1960 and 1961 at the proposed site with the dam located about 2 kilometers upstream from Troll-konufoss to divert water by a tunnel through the Mountain Burfell to a powerhouse located on the Thjorsa at the west side of the mountain. This site is subsequently referred to as the "Lower Site."

Report No. 2 - Summary Report on Burfell Project - Thjorsa River, Iceland, November 4, 1961.

This report presented an appraisal of a four-unit run-of-river plant totalling 130 MW in an underground powerhouse with a low diversion dam in the river at the Lower Site. The studies leading to the selection of the run-of-river development disclosed that a dam for storage was too costly for an initial stage of development. However, the development was laid out to provide for the future construction of such a storage dam. The studies showed that a run-of-river development at the Lower Site was capable of producing low cost power and energy.

Report No. 3 - Appraisal Report on Burfell Project - Thjorsa River, Iceland, March 1962.

This report presented an appraisal of a six-unit run-of-river plant totalling 156 MW and located at the Upper Site, which is about 3 kilometers upstream of the Lower Site. The development would be run-of-river and involve diversion around the north end of the Mountain Burfell to the Fossa, a short distance upstream of its junction with the Thjorsa. An underground powerhouse of the tailtunnel type was positioned midway between the diversion dam on the Thjorsa and the tailtunnel outlet at the Fossa. This development was somewhat more economical than the run-of-river development at the Lower Site, as presented in Report No. 2. The development at the Upper Site was suggested in Report No. 1 as an alternative to the Lower Site. Also, field reconnaissance in the fall of 1961 showed that location to have promise for run-of-river development. A development in that same general area also had been considered some thirty years earlier by a Norwegian engineering firm. The studies of Report No. 3 also presented an estimate of cost for a small initial storage at Thorisvatn.

Report No. 4 - Burfell Project - 60 MW Plant - An Appraisal Report, December 1962.

This report presented an appraisal of a 60 MW plant of two units at the Upper Site. Such a smaller development was intended primarily to serve the normal system load growth of Southwest Iceland without any large new industrial load. The studies showed the 60 MW plant to have relatively low unit power and energy costs, but unit costs which were somewhat higher than for the larger plant presented in Report No. 3.

Report No. 5 - Project Planning Report - Burfell Project (in 2 Volumes), January 1963.

This report may be considered as the basic Project Planning Report for the Burfell Project. Extensive field investigations were conducted at the Upper Site throughout 1962. The report incorporates the results of these investigations including hydrology, geology, topography, and construction materials. The report envisioned a 180 MW six-unit ultimate plant with an underground powerstation. It also appraised the costs for installing the fourth, fifth, and sixth units initially.

Report No. 6 - Letter Report Supplement to Project Planning Report - Burfell Project, March 1963.

This report reappraised the project presented in Report No. 5 on the basis of three successive stages involving two 30 MW units each. The diversion features were modified to add the Bjarnalaekur Canal and its control structure accompanied by lowering the level of, and redesigning the Diversion Inlet and Canal. Also, the silt excluder was eliminated. This study envisioned a project developed to serve the normal load growth of Southwest Iceland, but no large initial industrial load. Report No. 6 was an interim report.

Report No. 7 - Supplementary Report to Project Planning Report - Burfell Project, April 1963.

This report supplemented Report No. 5 and superseded Report No. 6 by presenting more detail on the project developed in three stages of two 30 MW units each. The Diversion Weir and Inlet were moved about 300 meters upstream and the remaining river diversion features, as presented in Report No. 6, were modified to fit that new location, except for the Left Bank Dike which was relocated to extend eastward to the Hekla lava front. Also, the diversion weir was redesigned to provide a flap gate section and an overflow section surmounted by flash boards.

Report No. 8 - Letter Report on Advanced Planning of Thjorsa Diversion Features - Burfell Project, May 1963.

This report presented planning of the Thjorsa Diversion features to reflect advances over the designs presented in Report No. 5. Most of these advances had been presented previously in Reports Nos. 6 and 7. The report also presented the results of some additional diamond core borings and other field investigations carried out subsequent to those presented in Report No. 5. Report No. 8 was based on ultimate development and did not directly consider stage construction. The studies showed very little change in project costs for the river diversion features from the costs presented in Report No. 5. The designs presented in this report were used as the basis for the hydraulic model studies now in progress.

Report No. 9 - Letter Report on Plant with 35 MW Units - Burfell Project, October 1963.

This report appraised the stage development of the project presented in Report No. 7 utilizing a unit size of 35 MW instead of 30 MW. The studies showed the larger units to represent a somewhat better project economically than one with the smaller sized units.

Report No. 10 - Second Supplementary Report - Burfell Project, October 1963.

This report appraised the Burfell Project to serve a one potline aluminium smelter and also the North Iceland loads in addition to the normal Southwest Iceland loads. The development was appraised on the basis of construction in four stages, with the initial Stage I involving three 35 MW units followed by three subsequent stages of one 35 MW unit each. Otherwise the project structures were the same as presented in Report No. 9.

Report No. 11 - Letter. Subject: Burfell Project with Above-Ground Power Station. February 10, 1964.

This letter presented the project modified from an underground power station to an above-ground power station located on the Fossa at the western end of Samstadamuli. This study showed substantial cost savings with respect to both the initial and ultimate project. Accordingly, the basic plan of development with the surface powerhouse was adopted for Burfell and engineering work commenced immediately on the preparation of design memoranda for the power features of the project. These memoranda were completed in draft form in mid-summer of 1964. A cost estimate of the project, as thus revised, was prepared on October 19, 1964.

Report No. 12 - Letter Report on Contract Documents for Stage I Construction - Burfell Project. January 1965.

This report presented the time schedule for the completion of the preparation of the Contract Documents and for the award of the contracts to permit commencement of power generation from the Burfell Project by the end of 1968.

REPORTS RELATED TO

BURFELL HYDROELECTRIC PROJECT

Report No. 13 - Power Market Study of Iceland, November 1963.

This report presented estimates of power and energy requirements for Iceland divided between the Southwest, Northern, Northwest and Eastern regions. The estimates were for the twenty-year period from 1963 to 1982, and included consideration of aluminium smelter loads.

Report No. 14 - Appraisal Report - Vordufell Pumped Storage Project, June 1963.

This report presented an appraisal of a pumped storage development at Vordufell, about 50 kilometers east of Reykjavik. The specific project appraised represented only a small portion of the potential and was planned to provide, primarily, energy reserves to the proposed aluminium smelter, as well as some reserve capacity.

APPENDIX B

BURFELL HYDROELECTRIC PROJECT
ALTERNATIVE SCHEDULING

General

Two alternative schedulings of the Burfell Project to that of the main body of this Report have been studied. One alternative involves scheduling the Burfell Project to supplement the Southwest Iceland Power Supply System in providing power and energy to the normal load with two complete aluminium smelter potlines. The first potline would develop its full power demand by mid-1969 and the second, three years later. The second alternative assumes no smelter loads and Burfell would be added to the System incrementally to serve normal loads only.

Project for Two Complete Potlines

The scheduling of the Burfell Project for Stage I with three initial generating units to serve loads which would include one potline would be identical with that presented in the main body of this Report. Providing the additional service to include the second potline with full load demand by mid-1972 requires the consolidation of Stages II and III into a single Stage. The fourth and fifth generating units would be placed in operation in early 1972. The main permanent equipment would be placed on order in late 1969. All of the civil construction would be accomplished in 1971 except for the Thorisvatn Initial Storage which would be completed in the summer of 1972 after initiation a summer earlier. The total load would require that the sixth unit of Stage IV be added by November 1973. The main permanent equipment for this unit would be placed on order in late 1971. The installation would be accomplished entirely in 1973. No other construction is required except the removal of the Írafoss Intertie to the Geithâls Substation where a 230 kV and a 138 kV bay would be added.

It is planned to take options for the supply of the main permanent equipment for the last three generating units at the time the bids are received for the first three units in Stage I. The decision as to whether or not to accept the options would be made at the time it became necessary to begin the equipment manufacture for the subsequent installations; thus the options would include provisions for price escalations tied to an acceptable index.

The construction methods and procedures for the Burfell Project would be identical to those discussed in Chapter V. The construction scheduling, however, would be changed in point of time as is shown by the bar graph of Exhibit 12A, attached hereto. The time schedule for Stage I represents no changes and would be identical to that of Exhibit 12 of the main body of this Report. Stages II and III would be combined into a single Stage with construction accomplished largely in 1971. Inasmuch as the two generating units would be placed in operation by the late winter of 1971-72 aimed for meeting the full demand of the second potline by mid-1972, it would not be necessary to complete the Thorisvatn Initial Storage until that same summer. The Stage IV construction would be accomplished in 1973 to place the sixth unit in operation by November of that year.

The construction cost estimates would be the same as presented in the main body of this Report, except that Stages II and III would be combined. Again the cost estimates do not include import duties and taxes, interest during construction, capitalized reserves or working capital.

The estimated construction costs by Stages divided as between domestic and foreign currency requirements are scheduled by years on both a commitment and disbursement basis on the attached Table B-1. The scheduled commitments are based on the construction schedule of Exhibit 12A. Differences between commitments and disbursements are accounted for by an assumed ten percent witholdings on construction and equipment supply contracts which would be released after contract completion and satisfactory equipment performance. The total disbursement requirements by years are estimated to the nearest 0.1 million U.S. dollars as follows:

Year	1964	1965	1966	1967	1968	1969	1970	1971
	1972	1973	Total					
Requirement:	1.0	1.2	3.5	10.5	9.4	2.8	1.3	4.4
	2.3	0.9	37.3					

The estimate for 1964 includes the $ 800,000 of "Preliminary Costs" in the Stage I estimate plus an additional $ 200,000 expended for the Project in the last six months of that year.

The estimated annual operation and maintenance (O&M) expense in U.S. Dollars, based on present cost levels, as each Stage is completed is as follows:

Stage	Initial Annual O&M Expense
I	$ 315.000
II & III	385.000
IV	420.000

The above costs may increase in future years dependent upon the effects of any inflation.

The estimates for average annual delivered primary energy production and delivered dependable peaking capability as units are installed would, for all practical pruposes, not change from the respective values presented in Chapter VII.

Project without Smelter Loads

The scheduling of the Burfell Project constructed to supplement the existing System in serving the normal loads only of Southwest Iceland based on the load growth studies presented in Report No. 13 of Appendix A would be as follows:

Stage	Number of Units	Year Completed
I	2	1968
IA	1	1975
II	1	1978
III	1	1981
IV	1	1983

Construction of Stage I would commence at the beginning of 1966. The Approach Canal, Sámsstadaklif Dike, Sámsstadaklif Sluiceway, Power Intake, Power Tunnel, Bjarnalækur Canal, Left Bank Dike, Burfell Reservoir Features and the Transmission line of Geithâls would be completed fully in Stage I. Transmission lines from Geithâls to Straumsvik, the associated two 230 kV bays in the Geithâls Substation and the Straumsvík Substation would not be needed in any Stage. The right Penstock and Surge Tank would be complete in Stage I as will the upper horizontal leg of the left Penstock and the left Surge Tank except for the emergency gate facilities. The remainder of the left Penstock and the emergency gate facilities would be added in Stage II.

The Stage I construction of the Powerhouse would include only the erection bay and two unit bays plus excavation for the third bay and of the Tailrace for the three bays. A unit bay would be added in each subsequent Stage together with the excavation for one bay and an associated part of the Tailrace, except that all excavation would be completed through Stage III. Most of the Accessory Electrical and Miscellaneous Mechanical Equipment would be included in Stage I, with the remainder installed as required for each incremental generating unit in each subsequent Stage.

The Diversion Weir and Bjarnalaekur Canal Sluice Structure would be constructed in Stage I the same as described for Stage I in the main body of this Report. Completion would be accomplished in Stage III.

Minimum provisions of the Diversion Inlet and Canal for only three units would be provided in Stage I. Appropriate additions would be made in Stages II and III. The Right Bank Dike would be constructed in Stage III.

The provisions of the Operators Village, Project Access Roads, General Plant, and the main Access Roads and Bridges in Stage I would be the same as discussed in the main body of this Report for the same Stage. Appropriate additions would be made to the first three items in each subsequent Stage. An addition would be made in Stage III to the main Access Roads and Bridges, the same as discussed for Stage III in the main body of this Report.

The Burfell Sending Substation in Stage I would include three bays, one bank of main power transformers and provisions for the 69 kV service. A third bank of transformers and a fourth bay would be added in Stage 1A. The last bank of main power transformers and the fifth bay would be added in Stage III.

The Irafoss Intertie would be installed in Stage 1A, then removed to the Geithâls Substation in Stage IV.

The Geithâls Receiving Substation in Stage I would include three 230 kV bays,one 70 MVA autotransformer, and five 138 kV bays. The second autotransformer would be added in stage 1A together with one bay in each of the 230 and 138 kV portions. A seventh 138 kV bay would be added in Stage III to serve a second transmission line to Ellidaár. Single bays would be added in each portion of the Substation in Stage IV to accommodate the autotransformer moved from Irafoss.

Thorisvatn Initial Storage would be provided in Stage III.

In general, construction methods and procedures for all five Stages would be similar to those discussed in Chapter V. A bar graph construction schedule is not included.

A Summary Cost Estimate by Stages is presented on Exhibit 13A, attached. The Estimate shows the division between domestic and foreign currency requirements for construction costs only, and is expressed in U.S. Dollars on the basis of 43 Icelandic Kronur to one U.S. Dollar. The Summary Cost Estimates are based on the detailed cost estimates used in the preparation of Exhibit 13 of the main body of this Report, but the detail is not presented in this Report. The cost estimates do not include import duties and taxes, interest during construction, capitalized reserves or working capital.

The Estimated Construction Costs by Stages divided as between domestic and foreign currency requirements are scheduled by years on both a commitment and disbursement basis on the attached table B-2. Differences between commitment and disbursements are accounted for by an assumed ten percent withholdings on construction and equipment supply contracts which would be released after contract completion and satisfactory equipment performance.

The total disbursement requirements by years are estimated to the nearest 0.1 million U.S. Dollars as follows:

Year:	1964	1965	1966	1967	1968	1969	1970	
Requirement:	1.0	1.2	4.2	7.9	5.3	1.8	0.0	
Year:	1971	1972	1973	1974	1975	1976	1977	
Requirement:	0.0	0.0	0.0	1.0	1.7	0.3	1.2	
Year:	1978	1979	1980	1981	1982	1983	1984	Total
Requirement:	2.4	0.5	2.0	3.8	1.2	1.1	0.1	36.7

The estimates for 1964 includes the $ 800,000 of "Preliminary Costs" in the Stage I estimate plus an additional $ 200,000 expended for the Project in the last six months of that year.

The estimated annual operation and maintenance (O&M) expense in U.S. dollars, based on present cost levels, as each Stage is completed is as follows:

Stage	Initial Annual O&M Expense
I	$ 280,000
IA	315,000
II	350,000
III	385,000
IV	415,000

The above costs may increase in future years dependent on the effect of any inflation.

The peaking power in MW which the Burfell Project can deliver at the Geithảls Receiving Substation as each Stage is developed has been estimated as follows:

Stage	Peaking Capability - MW
I	75
IA	111
II	148
III	183
IV	220

The average annual primary energy which the Burfell Project can deliver at the Geithảls Receiving Substation as each Stage is developed has been estimated as follows:

	Annual Primary Energy - GWh
I	600
IA	900
II	1190
III	1480
IV	1720

TABLE B - 1

BURFELL HYDROELECTRIC PROJECT

PROJECT SCHEDULED FOR TWO COMPLETE POTLINES

CONSTRUCTION COSTS

COMMITMENTS AND DISBURSEMENTS BY STAGES AND YEARS

DIVIDED BETWEEN DOMESTIC AND FOREIGN CURRENCY

IN MILLION U.S. DOLLARS

Year	Commitments			Disbursements		
	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total
A. STAGE I - THREE 35 MW UNITS						
1964	1.000	0.000	1.000	1.000	0.000	1.000
1965	0.600	0.600	1.200	0.600	0.600	1.200
1966	1.100	2.700	3.800	1.000	2.500	3.500
1967	4.100	7.500	11.600	3.700	6.800	10.500
1968	4.460	5.974	10.434	4.000	5.400	9.400
1969	0.240	0.100	0.340	1.200	1.574	2.774
Totals	11.500	16.874	28.374	11.500	16.874	28.374
B. STAGES II AND III - TWO 35 MW UNITS						
1970	0.000	1.400	1.400	0.000	1.300	1.300
1971	2.020	2.809	4.829	1.800	2.560	4.360
1972	0.674	0.570	1.244	0.894	0.919	1.813
Totals	2.694	4.779	7.473	2.694	4.779	7.473
C. STAGE IV - ONE 35 MW UNIT						
1972	0.000	0.595	0.595	0.000	0.500	0.500
1973	0.311	0.500	0.811	0.311	0.595	0.906
Totals	0.311	1.095	1.406	0.311	1.095	1.406
GRAND TOTALS	14.505	22.748	37.253	14.505	22.748	37.253

TABLE B - 2

BURFELL HYDROELECTRIC PROJECT

PROJECT WITHOUT SMELTER LOADS

CONSTRUCTION COSTS

COMMITMENTS AND DISBURSEMENTS BY STAGES AND YEARS

DIVIDED BETWEEN DOMESTIC AND FOREIGN CURRENCY

IN MILLION U.S. DOLLARS

Year	Commitments			Disbursements		
	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total
A. STAGE I - TWO 35 MW UNITS						
1964	1.0	0.0	1.0	1.0	0.0	1.0
1965	0.6	0.6	1.2	0.6	0.6	1.2
1966	1.8	2.8	4.6	1.6	2.6	4.2
1967	3.3	5.4	8.7	3.0	4.9	7.9
1968	2.2	3.6	5.8	2.0	3.3	5.3
1969	0.1	0.0	0.1	0.8	1.0	1.8
Totals	9.0	12.4	21.4	9.0	12.4	21.4
B. STAGE IA - ONE 35 MW UNIT						
1974	0.2	0.9	1.1	0.2	0.8	1.0
1975	0.6	1.3	1.9	0.5	1.2	1.7
1976	0.0	0.0	0.0	0.1	0.2	0.3
Totals	0.8	2.2	3.0	0.8	2.2	3.0
C. STAGE II - ONE 35 MW UNIT						
1977	0.3	1.0	1.3	0.3	0.9	1.2
1978	1.0	1.7	2.7	0.9	1.5	2.4
1979	0.1	0.0	0.1	0.2	0.3	0.5
Totals	1.4	2.7	4.1	1.4	2.7	4.1
D. STAGE III - ONE 35 MW UNIT						
1980	0.9	1.3	2.2	0.8	1.2	2.0
1981	1.6	2.5	4.1	1.5	2.3	3.8
1982	0.1	0.0	0.1	0.3	0.3	0.6
Totals	2.6	3.8	6.4	2.6	3.8	6.4
E. STAGE IV - ONE 35 MW UNIT						
1982	0.0	0.6	0.6	0.0	0.6	0.6
1983	0.5	0.7	1.2	0.5	0.6	1.1
1984	0.0	0.0	0.0	0.0	0.1	0.1
Totals	0.5	1.3	1.8	0.5	1.3	1.8
GRAND TOTALS	14.3	22.4	36.7	14.3	22.4	36.7